COMMERCIAL FRUITS OF INDIA

WITH

SPECIAL REFERENCE TO WESTERN INDIA

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FOREWORD

Dr. G. S. Cheema and his colleagues have asked me, as Director of the Imperial Bureau of Horticulture and Plantation Crops, to write a Foreword to their work on "Commercial Fruits of India", with special reference to Western India. I have accepted, not because I felt that my brief contacts with these problems in any way qualified me for so doing, but because I knew the authors were convinced that many of the fundamental principles of fruit production were shared in common throughout the horticultural world. I also knew they valued that rapid interchange of knowledge between horticultural scientists of all nations which such an information bureau as ours makes not only a possibility but a reality. I have read with real interest and profit the major portions of these 10 monographs on the most important fruits grown in Western India, and, while there are other valuable text books on tropical fruit culture dealing very briefly with far more species, I know of no book which gives such detailed treatment to many of the individual fruits dealt with in the present work. As a result, many a vague impression has taken concrete shape in my mind, and half formed queries have received a straight answer.

The authors have managed so successfully to inter-weave history and local tradition, established practice and scientific investigation, domestic consumption and the wider trade aspects of their subject that there is much information to sustain the interest of diverse types of enquirer.

The long experience of the writers is combined with their keen interest in the application of modern research results for the development of the fruit industry of Western India. Mr. R. G. Allan, whom long experience in the Central Provinces, United Provinces, and Baroda has amply qualified to speak, expresses the view that this book will prove a very considerable addition to fruit literature in India as a whole and will indeed become a standard horticultural work in so far as that country is concerned. I venture to predict that it will find many grateful readers even further afield amongst that ever-widening circle of people interested in the extended growth and popularization of Tropical Fruits throughout the world. Containing as it

does a mass of detailed information upon successful local practices with an up-to-date review of the results of the latest research—backed by an impressive bibliography of some 800 references—I feel I can confidently recommend it to the practical grower, the student and the investigator, and, on their behalf, as well as my own, I wish to congratulate Dr. G. S. Cheema, Mr. S. S. Bhat and Dr. K. C. Naik on the successful attainment of a truly formidable task, and to express our thanks to them for undertaking it.

RONALD G. HATTON

Director, East Malling Research Station

East Malling, Kent, England

PREFACE

I have read in considerable detail the manuscript of the handbook on fruit culture, "Commercial Fruits of India," written by Dr. Cheema and Mr. Bhat. I consider that it is interesting, up to date in its information and likely to prove a very considerable contribution to fruit literature of India, and in particular Western India. It is fully worth publication. The additional step of co-opting Mr. K. C. Naik, Horticulturist of Madras, who has had several years of experience in the Punjab and Bihar, has undoubtedly increased the All-India value and usefulness of the publication. In fact, it will become a standard horticultural book in so far as India is concerned.

R. G. ALLAN, M.A., C.I.E. (Kt.),
Commissioner of Agriculture (retired),
Baroda State, Baroda.

AUTHORS' PREFACE

This book on the major fruit crops of India describes chiefly the existing practices of fruit growing in its important aspects as they prevail in this country and more particularly in Western India. The fruit crops dealt with in it are banana, mango, citrus, guava, pomegranate, papaya, grape, sapota, fig and jujube. The information given in these pages is collected over three decades of work in the field of improving and developing the fruit industry in different parts of the country, mainly in Western India. Wherever possible, effort has been made to include an account of comparative practices prevailing in other tropical countries of the world.

Historically, fruits are found to have figured very prominently in the life of Indians from times immemorial. Jawaharlal Nehru ("Discovery of India", The Signet Press, Calcutta, 1946) states that as far back as the fourth century B.C. and even earlier in the pre-Buddhist period, horticulture was a prominent avocation in India. He quotes Ratilal Mehta to show that mango, fig, grape, banana and date were the favourite fruits of those days and that horticulture was practised on an extensive scale.

In A.D. 64, a Chinese embassy came to India and some welcome gifts brought to India then, according to Nehru, were the peach and pear trees. Later in A.D. 671, I-tsing (or Yi-tsing) visited the country as a pilgrim and "he tells us that fruits were abundant in India in those days". The same view was recorded by Paes, a Portuguese who, states Nehru, came in 1922 after visiting the Italian cities of the Renaissance, and remarked of the city of Vijayanagar—"it is full of fruit". Poets of front rank like Amir Khusrau, a Turk who settled in the U.P. and lived in the fourteenth century and a scholar in Persian, Hindi and Sanskrit, wrote poems on many subjects in which India excelled, including the mango fruit. All these together with the large-sized *lakh-bags* (orchards planted to 1,00,000 trees) established by Mughals and other lesser known Nawabs and Rajahs, all speak of the love for fruits that had permeated the Indians from the remotest periods of history. This is further borne out

from the fact that fruit is sanctified by religion and forms the principal food advocated by sages and saints and for use as offerings in temples and to men of light and learning. It is a paradox that notwithstanding this hoary past, fruit cultivation should still be an uncertain and risky avocation to those who resort to it and that fruit production should remain yet a hobby rather than be among the leading industries of the country, for fostering which nature seems to have contributed all that is congenial. Of all the limiting factors in the progressive prosperity of fruit culture, absence of a fund of tested and recorded information appears to be the most important. Fruit research being yet in its infancy, the fruit grower was largely allowed to plough his lonely furrow. Making the accumulated knowledge from observation and research available to growers, is a task of no small importance in any country, but is one of unexcelled value in India.

The subject of fruit growing in India did not receive until lately the attention of the State and the public which it deserved. In spite of the existence of a variety of conditions of soil and climate suited to the production of various fruits, India imports every year nearly three crores of rupees worth of fruits and fruit products both by sea and land. During the last quarter of a century, however, what with the influence of the agricultural and industrial depression which has swept over the world during the 'twenties and 'thirties, and what with the stimulus given by the Indian (formerly Imperial) Council of Agricultural Research, and some of the Provincial Governments and Indian States, a considerable awakening has resulted in this country towards the possibilities of fruit growing as an economic proposition. The valuable place that fruit occupies in a well-balanced diet because of its rich mineral and vitamin contents is being increasingly realised on all hands, and "Eat more fruits" and "Grow more fruits" are gradually assuming an importance as popular national slogans in this country.

Fruit research stations are now established in a few Provinces and States. Intensive work is being undertaken on fruits on which this country still maintains a monopoly production and also on other indigenous and exotic fruits of well-known varieties with a view to place the fruit industry on sound modern lines. Introduction of new varieties, isolation and

selection of the choicest indigenous fruits, improvement in the various cultural practices, control of diseases and pests, marketing, storage and preservation, as well as export are being tackled by workers at these research stations. Some of the Universities have also given this subject of fruit culture and preservation the prominence and status of a major subject in their agricultural teaching courses. As a result, the erstwhile haphazard system of fruit farming is rapidly giving place to improved, systematised and scientific methods of culture.

The present age is characterised by a steady drift of the educated among the rural population towards the urban areas as a direct result of various sociological factors, most important of which are the low values offered for farm products and the lack of recreation facilities. The high prices ruling after World War II have, however, altered these conditions considerably. Fruit growing, if carried out on right lines, offers the much needed diversification in agricultural farming, and has a special appeal to the best among the educated young men and retired officers and businessmen, both from the point of view of income and hobby.

The absence of literature on fruit culture has been felt as a serious void in this country. This is considered, therefore, an opportune moment to place before the fruit-minded public an account of the existing situation of fruit cultivation in this country. It is with a view to meet a long felt need that this book has been attempted.

In presenting this volume to the public the aim of the authors has been to put together matters of direct practical value to the fruit growers both present and prospective, in order to help them to make the profession an economic success. In its present growing stage, past conventions typified by the "rule of the thumb" methods are being subjected to critical tests and new theories and recommendations are accepted with considerable circumspection. The grower who is enthusiastic in his profession and eager to apply the latest available knowledge of the subject will, it is hoped, find in this volume a handy guide-book for day-to-day use. The book is also meant to acquaint the research worker with the existing methods and practices, so that he may plan the most fruitful lines of approach to the problems facing the industry in its present state. The student who

has to study the subject for his examination in the agricultural colleges and other institutions, and the general reader, who takes interest in the economic development of the countryside and the improvement of the national dietary, will also, it is hoped, find the information presented herein of some help and guidance. The authors have endeavoured to make each chapter self-contained as far as possible. With most of the fruits dealt with in this book, several aspects of culture, propagation, etc., necessarily possess a high degree of similarity. This fact entailed some repetition while treating subjects of, more or less, common concern to more than one fruit. In the interests of the reader, who may find it more convenient to have all available information on a particular fruit presented at one place, it has been decided to retain the order of presentation as it stands at present, even though it has meant at certain places a degree of repetition. If this volume proves of some service to these various classes of people, and helps to attract more educated people to the rural parts of this vast country, the authors will consider their labours amply rewarded.

Since the compilation of this book was undertaken, two books dealing mainly with the regional fruit production practices of the U. P. and Madras have been brought out. One is by W. B. Hayes of Allahabad and is entitled "Fruit Growing in India" (Kitabistan, Allahabad, 1945), and the other is on "South Indian Fruits" (Varadachary & Co, Madras, 1949) by K. C. Naik who is also one of the authors of the present book. These publications are a happy indication of the endeavour to meet the growing demand for information on this subject.

The authors are grateful to Dr. Ronald G. Hatton of the East Malling Research Station and Sir R. G. Allan, for reviewing the manuscript. The authors are thankful to Mr. D. Akenhead for helpful advice and in collaboration with Mr. C. St. C. Fielden of the East Malling Research Station for reading it through.

In addition to various periodicals and publications listed in the bibliography, the authors have drawn freely from a number of books such as "Manual of Tropical and Sub-tropical Fruits" by W. Popenoe, "The Book of the Mango" by W. Burns and S. H. Prayag, "The Cultivation of Citrus

Fruits" by H. H. Hume, etc. Many of the tables of analysis of fruits are taken from "The Structure and Composition of Foods" by A. L. Winton and K. B. Winton. The authors acknowledge their indebtedness to all the authors of these books and their publishers.

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The authors are indebted to Sir Datar Singh, Vice-Chairman, Indian Council of Agricultural Research and Mr. R. L. Sethi, Agricultural Commissioner to the Government of India, for their encouragement and for affording facilities for publishing this volume.

The book contains many references to the work done in the fruit research centres financed by the Indian Council of Agricultural Research and includes a great deal of experience gained through such research schemes. There are in it also a large number of references to the works published by scientists working all over the world. This book, therefore, represents the sum-total of efforts from a large number of horticulturists in the country, and the authors do not need, therefore, to make any apology for presenting the work to the fruit growing public. They will, of course, appreciate it if any one of the readers will kindly point out any errors that might have inadvertently crept into the various references cited in the text, so as to enable them to correct such mistakes in future revisions of this book.

G. S. CHEEMA
S. S. BHAT
K. C. NAIK

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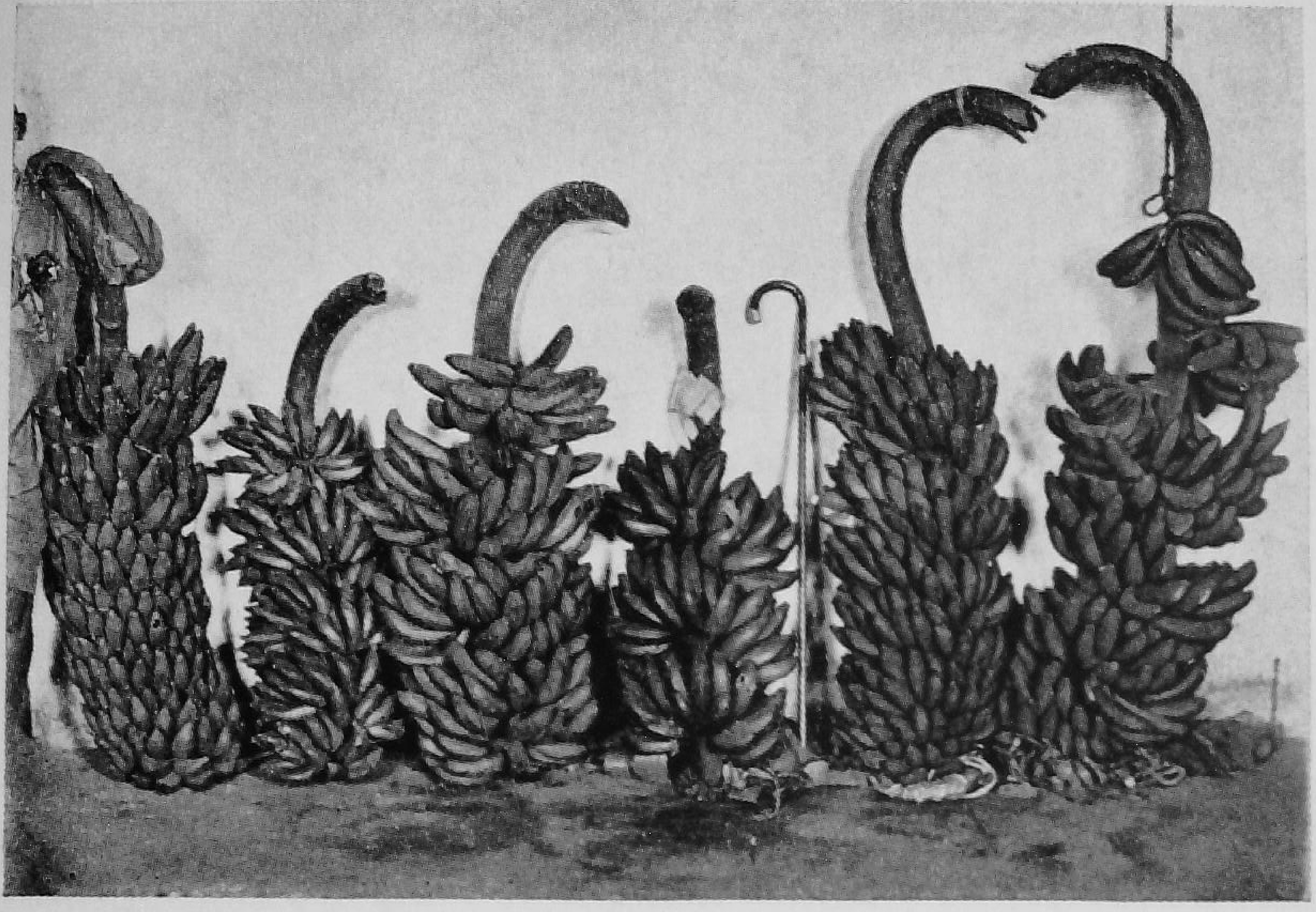
N.B. In the text the numbers in brackets after an author's name refer to the entry in the Bibliography at the end of each chapter.



BUNCHES OF THE CHIEF BANANA VARIETIES OF WESTERN INDIA.
R. to L. : RAJELI, SAFED VELCHI, BASRAI, LAL KELA, LAL VELCHI, KHASADIA.

Facing page 1.

CHAPTER I

BANANA (*Musa species*)

The banana is considered to be one of the most auspicious plants in India. It has accordingly enjoyed universal popularity in this country from time immemorial. In recent years, banana has also been found to be among the most valuable crops for implementing the drive for increased food production, claiming in well-kept plantations an annual yield even up to 60,000 lb. per acre. It can well rank, therefore, with any agricultural or horticultural crop as the most efficient means of enhancing food production. In a densely populated country like India where suitable land for cultivation is by no means available in unlimited extent, extension of banana plantations will provide perhaps one of the easiest methods of exploitation of land for making the country advanced on the road towards self-sufficiency in food production. It is not only the ripe fruit of banana that is prized as a food: the central core of the pseudo-stem, the inflorescence and the immature or unripe banana fruits are also no less prized as sources of food in Indian households. In parts of South India, banana leaf forms an invaluable substitute for dining plates. In the floral trade and even in small scale textile industries, banana fibre has been used fairly extensively. On all these considerations, banana can be regarded as a fruit of value, both for the rich and the poor.

One of the most popular fruits

The original home of this tropical fruit is considered to be the Malayan Peninsula or its neighbourhood. It has also been suggested that the banana might have originated in some parts of the tropical forests of Asia. The cultivation of banana has now extended to many parts of the world, although it is limited to the tropics. The fruit has become so popular and is so widely used that it is now available in all countries of the world, wherever transport facilities exist.

Origin

One of the botanical names of the banana appears to have been based on the legend that the serpent, which tempted Eve in the garden of Eden (Paradise), hid in a bunch of bananas. "Apple of Paradise", "Adam's Fig" and the specific name *paradisiaca*, all appear to have a distinct relation to ancient mythology. The word "banana" is said to have been adopted from an African Congo tribe.

Commercial importance

The commercial importance which this fruit has gained can be judged from the fact that its consumption in the United States of America and the European continent is enormous. The Islands of Honduras and Jamaica are among the chief banana exporting countries of the world. Brazil has also entered the competition and her exports have increased rapidly in recent years. The world trade in banana has been more than doubled during the last thirty years or so. Before World War I, it averaged slightly over a million tons of fruits or about 60,000,000 bunches annually. The total export trade of banana in the year 1930 amounted to about 2,000,000 tons of fruits or about 115,000,000 bunches. But there was a slight decline in 1931.

World production of bananas for overseas export during 1937 was more than 2·5 million tons. This was concentrated mainly in Central and South America and in the West Indies with Jamaica as the largest single producer, Mexico being the second largest.

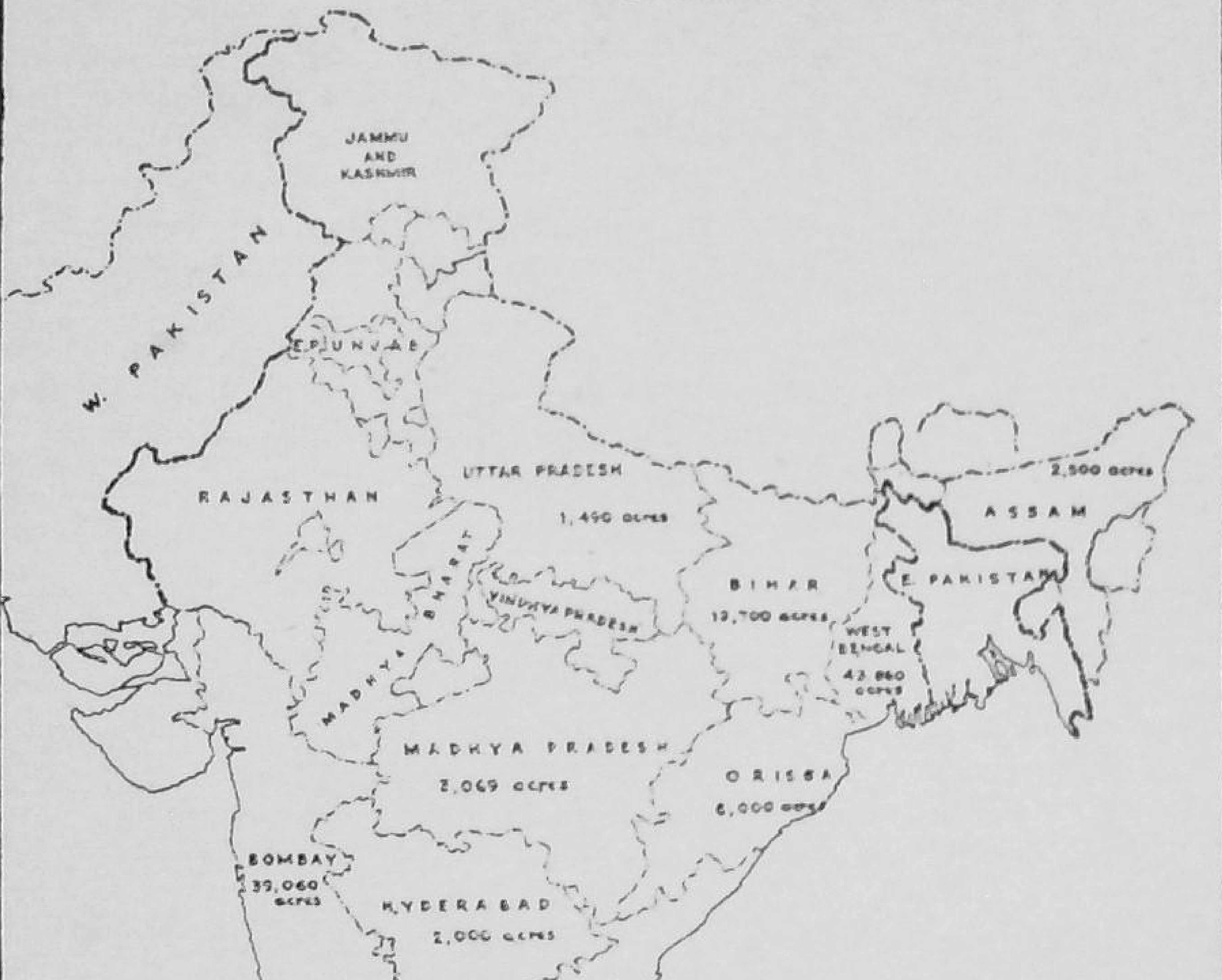
Sierr (84) gives an account of the plantation of the United Fruit Company at Tiquisata, Guatemala, with an acreage of 125,000 hectares and said to be the most modern and largest banana estate in the world.

The leading countries importing banana are the following:

United States of America	1,210,000	tons
United Kingdom	272,000	,,
France	111,000	,,
Japan	92,000	,,
Germany	87,000	,,
Canada	69,000	,,

High class varieties like the Gros Michel or Claret, which slightly differ from the Indian commercial varieties, hold the monopoly of world trade of bananas.

DISTRIBUTION OF ACREAGE UNDER BANANA IN INDIA



As stated above, the banana which originated somewhere in the tropical forests of Asia—in the Malayan Peninsula or the neighbouring countries—is now extensively cultivated under a variety of soils and climates in Jamaica, Costa Rica, Cuba, Honduras, northern shores of Columbia, Central America, Canary Islands and the West Indies, besides the Indian Union. These countries, excepting India, export banana to the European countries throughout the year. Most of the other tropical countries too grow banana to a limited extent to supply their own local demand for the fruits as in India.

Distribution

The chief regions in India which grow banana extensively are Madras, Travancore-Cochin, West Bengal and Bombay States. The total area under banana in India is 306,011 acres according to latest available data. It is mainly distributed as follows:

Chief growing regions in India

1.	Madras	128,163 acres
2.	Travancore-Cochin	47,504 ,,
3.	West Bengal	43,880 ,,
4.	Bombay	39,060 ,,
5.	Mysore	18,609 ,,
6.	Bihar	12,700 ,,
7.	Orissa	6,000 ,,
8.	Central Provinces	3,069 ,,
9.	Assam	2,500 ,,
10.	Hyderabad	2,000 ,,
11.	U. P.	1,490 ,,
12.	Coorg	1,036 ,,

Generally speaking, there are three distinct regions in India in respect of production and consumption of bananas. The Northern and the North-Western parts constitute essentially consuming centres, while South India, North-Eastern India and the Bombay Presidency comprise the main producing areas. The rest of India produces limited quantities of banana which are either sufficient for home consumption or have to be partially supplemented by imports.

The prevalence of frost and severe winter conditions preclude extensive cultivation of bananas in parts of the North and North-West India, particularly near the foot of the Himalayas.

A number of choice table varieties is, however, cultivated along the Ganges in the United Provinces, Bihar and Bengal, the tracts around Hajipur in North Bihar and Chandranagore in Bengal being particularly noted for heavy production. It is believed that parts of Orissa, Bengal, lower parts of Assam, Bihar and the United Provinces and South India possess abundant scope for extension of areas under this fruit.

In South India, Trichinopoly (Tiruchirapalli) which exports the largest quantity of bananas, in some years exceeding 550,000 maunds, and Malabar which is reported to possess about 52,000 acres, are entitled to be ranked as the premier banana producing centres. The Cauvery delta or banks in Coimbatore, Tanjore and Salem districts also constitute very important producing centres. The Lower Palni Hills are noted for the cultivation of some excellent hardy varieties of banana known as *Sirumalai* and *Virupakshi*, entirely under rainfed conditions.

In the State of Bombay, the chief banana growing districts are East Khandesh (13,679 acres), North Kanara (3,619 acres), Thana (2,614 acres), Poona (1,457 acres) and Satara (995 acres). In the North Kanara district, the banana is grown as an inter-crop in spice and coconut gardens. In the Thana district, Bassein is noted for its cultivation of a large number of banana varieties. In the Poona district, the Junnar and Walha regions grow banana on a large scale. Jalgaon in the East Khandesh district is known to export a large quantity of the *Basrai* banana to other parts of India, chiefly the northern States. This variety is grown in the surrounding villages like Asoda. Being a highly-profitable variety, the *Basrai* banana is of late extensively grown in the Gujerat regions which lie north of Bombay and have considerable advantage of nearness to the northern and north-western parts of India which are the consuming areas (16).

Classification

In a paper on classification of the bananas, Cheesman (33) recently has attempted to finalise the classification of this important fruit. He has made pointed reference to the distinction between the classification of the cultivated varieties and the general taxonomy of the genus *Musa* L. and has stated that either of these requires a different technique for its solution. Overlooking

this important and obvious fact, several workers have endeavoured to classify according to their own standards, causing a great deal of confusion. Cheesman has adopted the cytological basis for the classification of species, and states that chromosome number in *Musa* is not only a safe criterion of relation, but the best. Dodds and Simmonds (42) report that all the cultivated bananas occur within the group with a basic chromosome number of eleven, the majority of edible varieties being triploids ($3x=33$), but experimental hybridization has given also tetraploids ($4x=44$), a few higher polyploids, and some aneuploids.

Banana belongs to the Natural Order *Scitamineæ*, genus *Musa*. According to Cheesman, Linnaeus used originally two specific names for the edible bananas, *viz.*, *paradisiaca* and *sapientum*, but later three species were generally accepted as follow:—

1. *M. paradisiaca* for those which yield fruits of a starchy consistency, not usually consumed except after cooking, and popularly known as plantains.
2. *M. sapientum* for all dessert bananas except of dwarf habit.
3. *M. Cavendishii* (Lamb) for dwarf bananas, known as Canary or Chinese bananas.

Cheesman dismisses the last as invalid, since Cavendish has certain tall mutant forms resembling Gros Michel, which fact offends botanical justification for according a specific rank to these horticultural forms. He also states that it is unsound to distinguish the dessert bananas from the so-called plantains, as the quality based on starch and sugars is largely a varietal rather than a specific character in *Musa*. To associate persistent male flowers with *paradisiaca* and deciduous male flowers with *sapientum*, as Linnaeus had once done, is also not accepted by Cheesman as this is no better standard than starchiness. *M. paradisiaca* is the oldest name in the genus and has every claim to be regarded as the most suitable name, till the existing taxonomic confusion is unravelled. Cheesman suggests that in view of parthenocarpy, polyploidy, sterility and accumulated mutations in the cultivated varieties, *M. paradisiaca* should be applied to cultivated forms. The combination, such as *M. paradisiaca* sub-species *sapientum* as has been

employed by some, has been dubbed as "taxonomically unsound" by Cheesman. Dodds and Simmonds (42), have proved that the name *M. sapientum* of Linnaeus was applied originally to an interspecific hybrid. This lends force to the argument that *M. paradisiaca* should stand as the correct name for edible bananas.

All over the world, however, the term banana is now widely accepted as the trade name for all edible varieties of the fruit. In South India, on the other hand, all varieties are designated under the group name of plantain. Originally, the word banana was commonly applied to the varieties which are eaten raw and plantain to those which are eaten after cooking. Pope (76) also does not consider that any such clear differentiation exists at present. In accordance with the almost universal usage it seems appropriate that banana should be used for all edible varieties, whether they are used for table or cooking purposes.

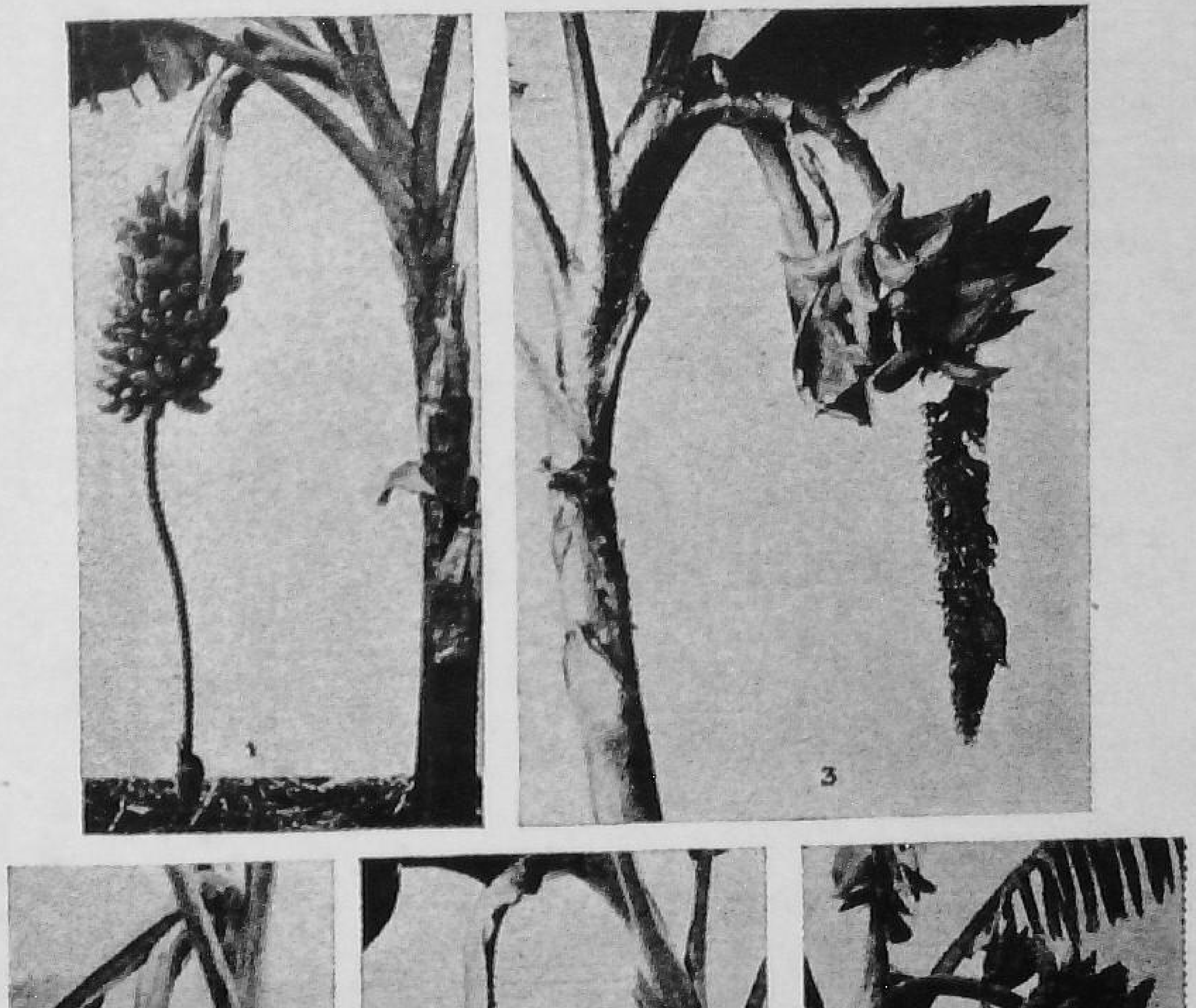
The most important commercial varieties of the Bombay Presidency are briefly described below:

(1) *Mindoli* (*Mhaskel*):—Tall plant, bearing bunches with about fifty thick-skinned yellowish fruits, having three clearly marked edges on them. Fruit not suitable for export.

(2) *Rajeli* (*King banana*):—Robust tree, with yellowish green stem and long narrow leaves. Fruit usually eight to ten inches long and one to one and a half inches in diameter, yellow in colour, and plano-convex, gradually converging to the stalk. Tip of fruit contracted with a distinct hard brown beak. Extensively grown in Bassein and well suited for drying purposes. The commercial product *Sukeli* (sun-dried banana) is prepared from this variety.

(3) *Soni* or *Sonkel*:—Tall plant, with sparse leaves and reddish tinge on both sides of peduncle; fruit sweet, and not easily separated from the stalk; has good keeping quality.

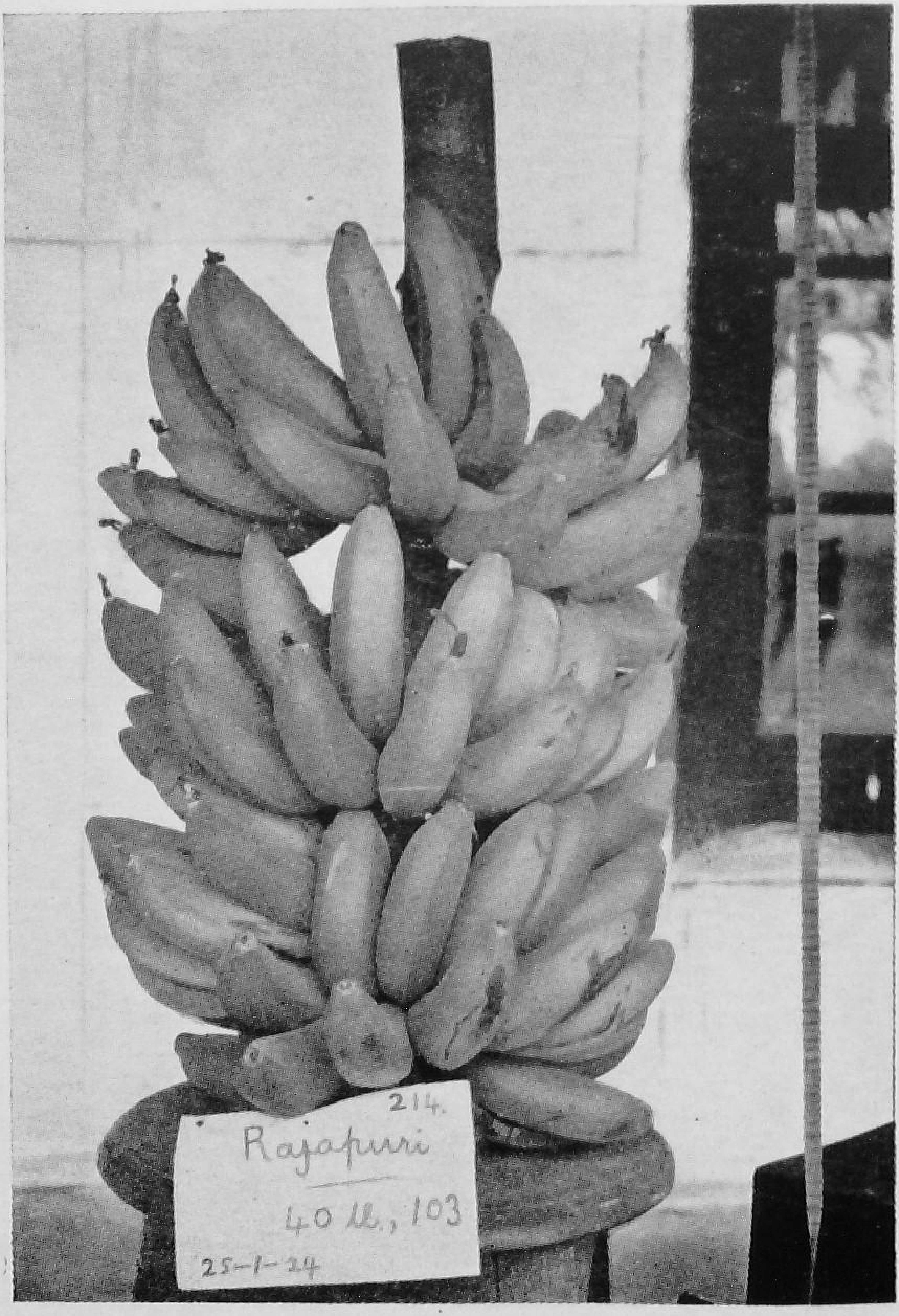
(4) *Velchi*:—Tall plant, with fruit tapering towards the stalk, and slightly sour in taste. Fruit small in size and yellow when ripe. Skin very thin and



BUNCHES OF LEADING COMMERCIAL VARIETIES OF SOUTH INDIA
(1) POORAN (2) RASTALI (3) NENDRAN (4) MANTHAN AND
(5) SIRUNIALI.

(*Courtesy* : K. C. Jacob, Assistant Systematic Botanist, Coimbatore.) *Facing page* 6.

BUNCH OF RASWEL BANANA. *Facing page 6.*



BUNCH OF RAJAPURI BANANA. *Facing page 7.*

papery, pulp whitish and highly agreeable; very delicious and high quality fruits. This is called *Safet* or white *Velchi* while a type approaching the *Sonkel* in quality is named *Lal Velchi* (red *Velchi*). The variety called *Mitka* in Karnatak is akin to *Safet Velchi*. The *Rasbali* which is a fair keeper and is a much superior variety is closely related to *Velchi* in morphological characters.

(5) *Lal Kel* (Bassein Red):—Tall plant, leaves very long and green with stalks of a dull purple tinge; fruit usually about eight inches long and 1·5 inches in diameter, oblong, cylindrical, slightly falcate, tapering slightly towards either end, beak hard, skin red and flesh yellow. One of the most popular types in the Bombay Presidency.

(6) *Basrai*:—Dwarf stem; leaves broad; skin yellowish green even when fruit is ripe; delicate, fruit long and uniformly thick; poor keeper.

(7) *Walha* (*Rajapuri*):—Dwarf stem; fruit short and thick near the stalk, tapering towards the beak; drops from the stalk easily when ripe; ridges distinct on the fruit; medium keeper and medium quality; pulp is stringy in the centre.

(8) *Mutheli* (Butter Banana):—Dwarf stem, with broad and short leaves; fruit medium, thick and round, bow-shaped, sweet taste; bunches thickly packed, fruit yellow when ripe; base of leaves very oblique.

In Bassein, nine varieties of banana are chiefly cultivated, and of these *Lal Kel* and *Lal Velchi* are the most popular. Of late, however, *Safet Velchi* is gradually gaining more demand. Commercially, *Sonkel*, *Velchi*, *Basrai*, *Lal Kel* and *Rajeli* are considered to be the choicest dessert varieties in Western India.

Of the numerous varieties grown in the Madras State, *Poovan* (syn. *Karpura Chakrakeli*) is easily the most important from the commercial point of view, accounting for about 70 per cent of the total production in southern districts. On the Malabar coast, *Nendran* is the most popular variety, while the *Sirumalai*, the fruits of which have fine flavour and taste and good keeping

quality, is largely grown on high elevations. *Monthan*, *Mauritius*, *Rasadali* (syn. *Rasthali*), *Pacha Nadan*, and *Bontha* comprise the other important cultivated varieties in the central and southern parts. Of these, *Monthan* and *Bontha* are grown for culinary purposes. In the Godavari, Ganjam and Vizagapatam districts, *Chakrakeli* and *Karpura Chakrakeli* (syn. *Poovan*) are the most popular table varieties, while *Monthan* and *Bathisa* are grown for cooking purposes.

The *Nendran* and hill bananas are noted for long commercial storage life, keeping well for about 15 days after harvest. The former variety can be dried, and is also used largely for making chips, several kinds of sweets, as well as for preparing jelly, jam and preserves. It bears the largest sized fruits, and because of this character it is considered locally to be a poor man's meal. *Poovan* and *Mauritius* keep well for about a week, as also the *Rasthali*, which is, however, unfit for export trade purposes as fruits shed easily from the bunches, while *Mauritius* fruits get slightly discoloured in transit. *Rasthali* is considered to be one of the popular table varieties in some parts of South India for its fine flavour and taste, but it has a meaty pulp with a tendency to form hard lumps in flesh. The white *Chakrakeli* is a greater favourite among the consumers in the northern parts of South India. Because of its hardiness, high yield and fair keeping quality, *Poovan* commands popularity both among growers and tradesmen and, therefore, claims the largest area in the South. *Monthan* is also a good keeper, but being of poor quality and fit only for cooking, it does not command as much market value, except close to urban areas. *Chakrakeli*, though very highly esteemed for fruit quality, is not very adaptable and is difficult to grow under adverse conditions of culture, climate and soil.

Kaio, a Hawaiian variety of banana, has been introduced into South India and is being grown in the Banana Experimental plot at Coimbatore. The fruit is 6·5 inches long, oblong to spindle shaped and resembles *Nendran* the Malabar Banana in respect of taste and flavour.

Champa, *Decca*, *Murtaban* and *Pankela* are the main commercial table varieties in Northern India.

A wild banana, *Musa superba*, is also seen growing in many forest areas. In Bihar, Eastern Himalayas, Assam Hills, Mani-

pur and Burma, this type is seen growing wild. Its fruit is full of seed and is not edible. It is chiefly used for its leaves by the local wild tribes.

The *Musa Fehi* Bert variety is reported from the Tahiti Islands (17). This species is easily distinguished by its erect bunches, which never droop as in the other species, a feature said to be met with also in the banana *Kusaie* of the Hawaii Island.

Some types of bananas like *Musa textilis* L. Nee, are well known for their fibre, popularly known as the Manila hemp.

Soil

For its successful cultivation, banana requires a rich loose soil. The sandy soils of Bassein and the coastal tract of the North Kanara district are very well suited for its cultivation. In the Konkan, most of the valleys in the ghats (mountain ranges), where water supply is plenty, atmosphere is damp, and humus in the soil is sufficient, are found to be very favourable for the banana to thrive. In heavy, ill-drained and shallow soils, the banana is often a prey to the Panama disease, caused by the fungus *Fusarium oxysporum* var. *cubense*.

At Walha in the Bombay Presidency, banana is grown in black cotton soil, about four to five feet deep. This soil is well drained being situated on the banks of streams and nallas. The banana crop in such a soil is, however, not as productive as in the sandy soils of Bassein. The medium black and lighter soils of Khandesh are also used for planting banana, provided irrigation facilities exist.

In the Presidency of Madras, banana is grown under a variety of soil conditions from the heavy clay but well drained soils of some of the deltaic tracts of Godavari and Kistna to the slightly open or loamy slopes of the Lower Palni hills. The virgin lateritic lands on the hill slopes of the Malabar coast, the alluvial or heavy loam of the wet paddy lands in most of the districts, and the alluvial soils along the Cauvery banks as well as the garden soils of various composition in Coimbatore, all appear to suit the crop, provided good drainage and heavy application of manure are provided for, especially in soils deficient in fertility. Banana plantations of nearly a hundred years of age are found thriving along the rich banks of Cauvery river in the Tanjore district and near Aduthurai.

Dunlop (8) opines that bananas do not grow on saline

soils, which prove dangerous if the salinity exceeds 0·05 per cent. Damage caused to banana plants depends upon the soil texture and the salt concentration. The optimum soil texture is reported to be as follows:—

Sandy loam	..	..	0·03 per cent.
Clay loam	..	..	0·045 ,,
Medium clay	..	..	0·050 ,,
Heavy clay	..	..	0·070 ,,

Soils which are best suited for banana have a fair quantity of lime and humus. Alkaline lands are said to improve by growing banana on them. Richly manured fields as in the cases where betel vine plantations existed previously produce good crops of banana, even without additional manuring for about two years. If the soil is stiff clay, it is loosened by the addition of village earth and sand. Rich scrub soils and soils with plenty of humus and free from excess of salts are very good for this crop. In general, banana is rather exacting in its soil requirements, and one has to go into the details of the soil selected before planting. A soil which is about two feet deep with a porous subsoil constitutes the minimum requirements for successful banana cultivation.

Climate

Banana is essentially a tropical plant and grows in warm humid climates better than in cold dry climates. Tracts where there is a chance of frost occurring during the winter, are not safe for its cultivation. Low temperature damages or kills the plant tissues and hinders the development of the fruit, affecting its quality. The district of North Kanara is perhaps the most ideal region for the cultivation of banana in the Bombay Presidency. But due to lack of irrigation facilities and means of transport and marketing, the cultivation of banana in this district is not as extensive as it deserves to be.

Taller varieties as a rule seem to flourish in warmer and moist climates than in cooler and drier climates. The loss due to high winds can be minimised in the case of tall varieties of bananas by planting thick wind-breaks. *Euphorbia tirucalli*, Linn and *Sesbania aegyptiaca* Pers, make useful wind-breaks in the Deccan. *Dalbergia sissoo*, Roxb. can be used as an effective wind-break in Sind. In the Khandesh dis-

tricts temporary wind-breaks of dry *tur* stalks (*Cajanus indicus* Speeng) or other similar material are erected on the western and southern sides of the plantation to cut off the hot wind from scorching the banana plants during summer, especially where irrigation water is scanty. *Lal Kel* does not seem to display its original attractive characteristics when grown in the dry districts above the ghats, and perhaps on this account, it is also observed to be a very poor yielder in the Gujerat tract.

During the years 1925, 1929 and 1934 most of the banana crop in the central Deccan districts was destroyed by the severe frost, though the cold wave lasted only for a short period, each time. The temperature went down to below 35°F in shade at many places and in some cases it reached the freezing point. It is observed that some types of banana are slightly more resistant to frost than others, but when temperature falls below freezing point, all types suffer equally badly. *Walah* or *Rajapuri* seems to resist ordinary cold better than *Basrai*. Leaves and tender stems of the *Basrai* got scorched and the growth of the plants was checked for about three months as a result of frost in the Khandesh district.

Like low temperature, strong wind is detrimental to the well-being of the banana plant. Very heavy winds may damage even the dwarf types of banana like the *Basrai* and *Walha*. In sheltered situations, however, the plantation may thrive well. It is chiefly on account of low temperatures during winter and high winds during the summer that bananas of good quality cannot be successfully grown in the Eastern Punjab and parts of the U. P.

Banana stands as heavy a rainfall as 150 inches or more per annum. About 70 to 80 inches of rainfall, if well distributed, is good for its cultivation. Heavy rain is not so injurious a factor to banana as low temperature, continuous strong wind or heavy clay soils. But if copious irrigation is available, the shortage of rains will not in any way discourage banana cultivation. Trenching of the planting area is found essential in heavy rainfall tracts, in order to drain away excess of water in the soil. Ordinarily, too much of stagnant water in the soil is injurious to the plantations. Stagnation of water encourages *Panama* and other fungus diseases.

Before planting suckers of banana, the land should neces-

sarily be well tilled. It is very beneficial to have the land deeply ploughed and heavily manured with farm yard manure. In Bassein, the land is flooded to soften the soil and a weak later it is ploughed crosswise. This is followed by harrowing and levelling. In Bombay State the land is allowed to get heated for a few months. In May, *rabbing* (burning brushwood, etc., on the area for heating the soil) is done. With the fall of the first monsoon showers, the land is again ploughed, harrowed, levelled and planted. In the vicinity of Jalgaon, the land is well ploughed and harrowed before suckers of *Basrai* banana are planted.

Preparatory tillage

The spacing for planting varies with the variety as follows:—

	Spacing of Planting
Lal Kel	9-10 feet apart
Lal Velchi	8-9 ,, ,,
Mutheli	8-9 ,, ,,
Safet Velchi	8-9 ,, ,,
Rajeli	7-8 ,, ,,
Basrai	5-6 ,, ,,
Mhaskel	5-6 ,, ,,
Lokhandi	5-6 ,, ,,

It is found by experience that a spacing of eight feet is suitable for the purposes of interculture.

The size of pits taken for planting suckers also varies according to the nature of the soil. In heavy black soils, pits are generally larger and deeper, being sometimes as big as $1\frac{1}{2}$ ft. by $1\frac{1}{2}$ ft. each. In lighter soils, it is not necessary to have such big pits. Fawcett (46) opines that larger pits give a better growth in the start to the suckers than smaller ones do. In Queensland it is reported that bananas are planted 12 to 15 feet apart in the case of dwarf varieties, and 20 to 25 feet apart in the case of tall varieties.

Planting is done in the Bombay Presidency in furrows taken crosswise at a distance of $4\frac{1}{2}$ ft. to 10 ft. each way. Small suckers are selected and planted at the crossing of the furrows in the pits already prepared. Irrigation follows, if it does not rain. Planting is generally done after the break of the rains. When the suckers shoot up, the furrows are broken by hoeing the land

crosswise frequently during the monsoon as the conditions of the soil may permit. Ten to fifteen cartloads of farm yard manure are added to an acre of land. After the rainy season, beds and water channels are again prepared and irrigation is resumed in beds between rows of trees, which are earthed up and thus supported by raising the soil at their foot.

In the Madras Presidency, 800 to 1,250 suckers are planted to an acre depending upon the variety. Along the Malabar coast (west coast of India) banana is often planted as an intercrop amidst areca-nut and cocoanut plantations. It is also planted as a shade crop for coffee and mandarin orange plants in South India.

In the drier tracts of Eastern Punjab, it is customary to plant bananas along with mango trees as shade or nurse crops. This practice is also prevalent in the Gujerat districts, in the early stages of mango plantations.

Selection of suckers for planting

Banana is usually propagated by suckers, a large number of which spring up from the base of the mother plants. Suckers may be planted in the beginning of the monsoon, that is, in the months of June-July. The selection of good suckers for planting is an important item requiring careful attention of the growers as this operation largely influences the future plantation and the yield. It is difficult to define accurately the type and bulk of suckers, which may be considered good for planting. Suckers of the following type are observed by experience to be useful and to yield satisfactory results:—

(1) Sword sucker which has a vigorous shoot, thick at the base and sharply converging towards the end with few linear leaves from which the name, sword sucker has arisen. Such suckers are preferred to ordinary suckers.

(2) Suckers less than three feet in height and selected from healthy and mature plants. These too are found superior as planting material.

Large suckers might bear fruit earlier than smaller ones but their bunches are generally small. It is, therefore, necessary to select small sword suckers, which are in a vigorous growing condition unlike ordinary or "water" suckers. Bowman (18) found that sword suckers produce the largest fruits.

Chona (36) has shown that to propagate healthy suckers it is necessary to separate from affected suckers the underground stem or corm which is usually free from infection, and plant the same after dipping in 2% copper sulphate solution. The secondary suckers coming out of such corms will be disease-free.

In some parts of the Madras Presidency, the suckers are hardened after they are separated from the mother plants by keeping them in the sun until they wither. In the Bombay Presidency, the selected suckers are headed back to about two-thirds their original length, their roots and buds are cut cleanly and they are then dipped in a thick slush of cowdung and water. Finely powdered old, wood-ash may be dusted on them. The dipping of suckers in cowdung and dusting them with ash is reported to protect them from rapid drying in the open field until they sprout up and begin to grow.

In the case of *Basrai* banana, however, very small suckers are chosen for planting, since it has been found to prolong the growing period and also increase the yield.

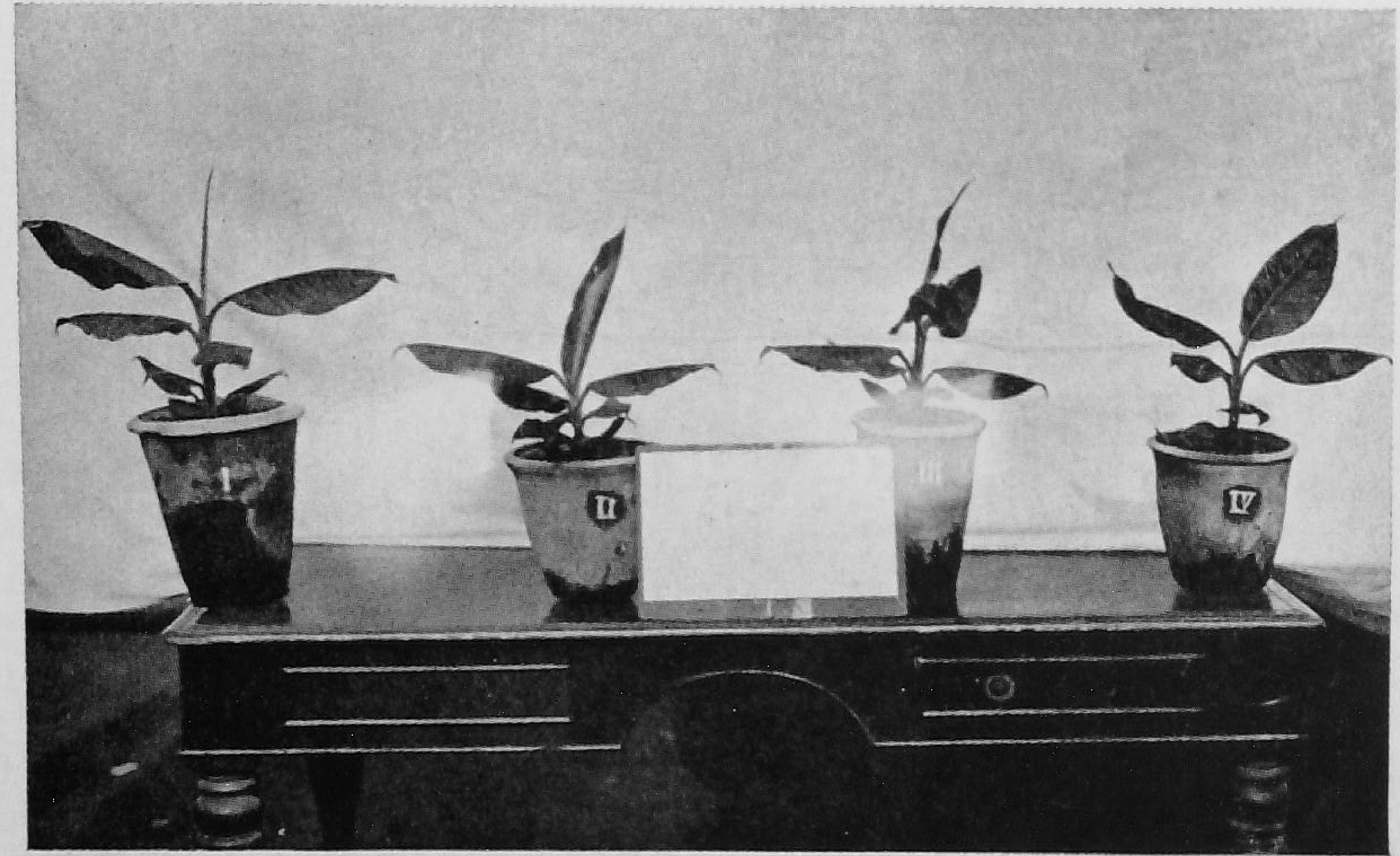
In Queensland, corms carrying two or three eyes only are used for planting (88). Bits, or rather sections, of old banana corms with one good bud are also used for planting.

In Brazil, banana soils after fifteen years of continuous cropping, are renovated by intensive cultivation, and the new plantings are made with bits of corm having two eyes planted on ridges (90).

In New South Wales it is recommended that suckers with the largest bulbs farthest from the parent, and with the most pointed and narrow leaves should be selected for planting. Those that are in the centre of stools, or have broad flat leaves known as umbrella or water suckers or those that are small and weak, and are found on stumps of the corm, are recommended to be discarded.

Planting

As has already been stated, planting is done in Bombay Presidency in July-August in pits, which are filled with soil mixed with a small quantity of farm yard manure about 5-10 lb. per pit. The soil is well pressed round the suckers and irrigation is given copiously. Suckers are planted straight. On planting the whole area may be flooded or water may be given in basins as required. After planting, water is given on the fourth and eighth days, if there is any



BANANA SEEDLINGS OF THE MANDRA BALE VARIETY.

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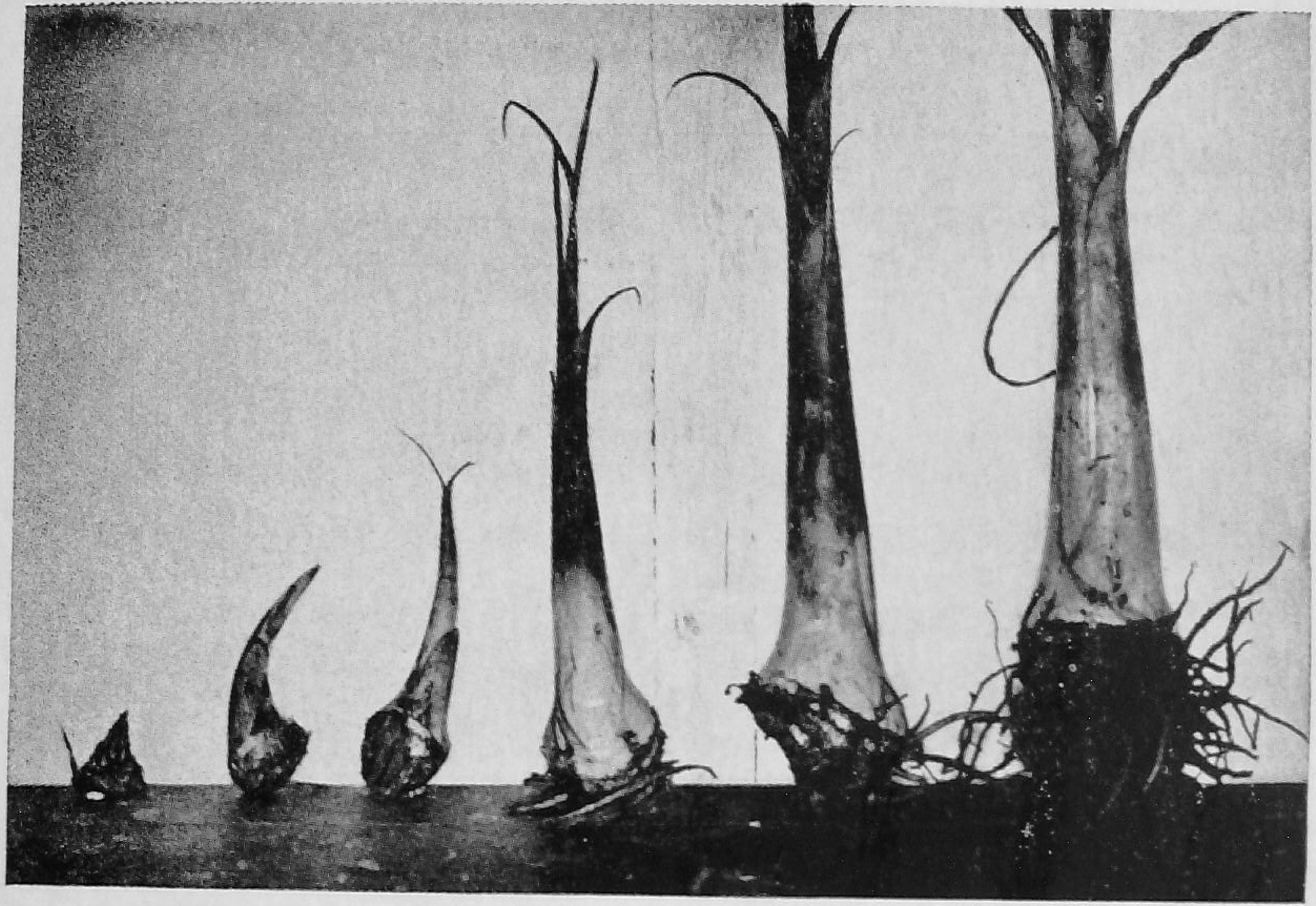


SWORD SUCKERS OF BANANA USED FOR PLANTING, SHOWING STAGES OF GROWTH. THE ONE IN THE CENTRE IS OF THE RIGHT STAGE OF PLANTING.

Facing page 15.

break in rains. Regularity in watering is essential for this crop. In Bassein no irrigation is given during the rainy season, but if the rains fail or the period between two successive rains is prolonged, the root zone is covered with banana leaves which form a mulch. The plants are hand-watered at the rate of two buckets (4 galls.) per plant at an interval of six to eight days.

Except during the rainy months, *Poovan* is planted in the Madras Presidency all through the year, some growers planting it in two or three seasons to take crop during the greater part of the year. The most popular planting season on the Cauvery delta is, however, February-March, but July to October plantings are also not unknown.

At Samalkota agricultural research station in the Madras Presidency, it has been found that planting of about six-week old suckers in May at a uniform distance of ten links overcomes the irrigation difficulties, met with in the case of the commonly prevalent method of planting in November (4). The latter plants are hand-watered for two or three weeks until the break of the south-west monsoon, and they mature their crop in ten or eleven months.

Banana is a heavy surface feeder. Not only does it require a copious supply of water but also heavy manuring. At Bassein

Manuring

(41) top dressings of the following mixtures are usually given after planting at regular intervals of one month for a period of three or four months:

Castor cake ..	.. 4-5 lb. per stool
Sulphate of ammonia	.. 1½ lb. ,, ,,
Sulphate of potash	.. 10-11 oz ,, ,,
Superphosphate ..	.. 11-12 oz ,, ,,

Other oil cake may also be given in addition to the above at the rate of 6-8 lb. per stool twice or thrice a year.

Different varieties of banana receive different doses of manure at Bassein. For instance, *Lal Velchi* is manured thrice at an interval of a month with 4 lb. of castor cake each time. At times, the third application is of fish meal and castor cake at the rate of 5 lb. and 2 lb. respectively. *Lal kela* (Bassein Red) plants receive four doses at intervals of three weeks each as follows:—

1. 4 lb. of castor cake
2. 6 lb. of castor cake
3. 5-6 lb. of fresh fish and 2 lb. of castor cake
4. 4 lb. of castor cake if the bunch is well developed, or else 6 lb. of fish instead.

Near Jalgaon where banana plants receive sewage water, no other manures are usually applied.

In the northern parts of the Bombay State, a heavy dose of some quick acting manure is applied after the monsoon breaks, and after the plots are weeded and the dry leaves of the plants are cut off. Groundnut cake at the rate of 2-3 lb. is recommended by some in Madras as the nitrogen in this cake is said to be more readily available than in other oil cakes (96). Other oil cakes and fish guano are recommended in places where they are cheap. A popular manurial practice in the Cauvery deltas is to apply sulphate of ammonia at 224 lb. per acre in April-May, about two months after planting. This is followed by an application of 1,000 lb. of groundnut cake and 224 lb. of ammonium sulphate or ammophos in the fifth or sixth month. The third or last application is done in the ninth month, and this is similar to the first. Trenches 15″ wide and 9-12″ deep are opened between every two rows, and the earth thus dug out is spread over the beds along the rows of trees. According to another system prevalent in these parts, a light dose of 1/2 lb. groundnut cake is applied around each plant soon after the plants begin to grow; and 5-6 weeks later, another application of 1½-2 lb. of the same cake is made. Good crops have been obtained in some parts of the Bombay State by the application of 20 cartloads of farm yard manure and 1,000 lb. of sulphate of ammonia per acre.

In the case of the *Walha* variety, the usual practice is to apply farm yard manure and sheep dung. After the first ploughing, about ten cartloads each of cattle manure and of sheep dung are applied and harrowed in. Later on, about 40 lb. of cattle manure are applied per stool at an interval of six months. Sheep dung is applied only once in the beginning of the plantations.

At the Ganeshkhind Fruit Experimental Station, Kirkee, manurial trials have been conducted on the *Basrai* variety of

bananas on a large scale, with a view to ascertain its requirements under the Deccan conditions of soil and climate. The method of layout adopted for these trials was the Latin Square, and the manures excepting in the case of potash were apportioned on their nitrogen basis. These trials included the use of farm yard manure as the base; and sulphate of ammonia, castor cake, bone meal, potash and double dose of farm yard manure were used. Different manurial combinations were tried and it was found that the application of 5 lb. of castor cake per stool in conjunction with 40 lb. of farm yard manure was the most suitable for the crop.

In parts of South India where rice is grown in rotation with banana, some growers also apply a basket of rich organic manure to each stool of banana at the end of the third month after planting. About 40 cartloads of farm yard manure per acre is considered to be a suitable quantity by some, and it is applied about a month after planting. In the absence of farm yard manure, about 1,500 lb. of groundnut or other oil cake per acre have also been applied in some places. Tannery refuse mixed with farm yard manure is considered by still others to be of value for bananas.

If circumstances permit it is advisable to green manure the land before digging pits. Green manuring is good both in heavy and light soils. The banana being a surface feeder, addition of humus to the soil helps to encourage the growth of the plants and increase the yield subsequently.

For thriftless banana plantations in Trinidad an application per tree of 200 lb. of synthetic pen manure with or without one pound of muriate of potash was found to be beneficial (95).

Fawcett (46) recommends the mixture of the following manure for banana:—

1.	Sulphate of potash ..	344 lb. per acre
2.	Wagner's double phosphate	211 lb. ,, ,,
	or	
	Mineral superphosphate ..	530 lb. ,, ,,

This mixture is applied at the rate of 400 to 600 grammes (1 lb. to 1½ lb.) per plant, varying with the kind of phosphatic manure used in the combination. Care should be taken

to place the manure in a trench made around the stem, avoiding direct contact with the stem.

Bartlett (14) states that banana is a voracious feeder and it is essential to keep up the fertility of the soil by every possible means. Supply of humus to the soil is indispensable as this manure not only provides plant food but also retains moisture and improves the aeration of the soil. It creates favourable conditions for soil bacteria to act upon mineral matters, thus rendering plant food easily available. He further states that experimental tests have demonstrated the usefulness of the mixtures given below:—

1. 2 lb. of dried blood,
   $1\frac{1}{4}$ lb. superphosphate,
   1 lb. sulphate of potash.
   } per stool every six months.

2. $1\frac{1}{4}$ lb. sulphate of ammonia,
   $1\frac{1}{4}$ lb. superphosphate,
   1 lb. sulphate of potash.
   } per stool every six months.

Either of these mixtures can be applied in March and in October to every stool.

In Grenada heavy soils are found to need liming as they retain moisture and become acidic in reaction. Soils with pH value of 6·5 require one to two tons of hydrated lime per acre.

Irrigation

The banana plants require very heavy irrigation. A local proverb is current that "the banana plant asked for water to drink, when it was being carried away by the river flood." Apart from this exaggeration, it has been observed that on an average the plants require about 3 acre inches of water at each turn of irrigation in the hot months from February to May (2). Irrigation is given in most places once in eight to ten days. Stagnation of water in soil is not very congenial to the proper growth of the banana plant. Drainage of the soil is, therefore, essential for its successful cultivation. It is seen that in heavy soils, banana plants thrive better on raised ridges alternating with trenches, than in flat beds. Near Jalgaon, irrigation is given to banana plants every three or four days during the hot weather. After the rains, irrigation beds are prepared between the rows of plants and irrigation intervals are reduced with the approach of cold weather.

In the Godavari delta area, irrigation is applied in trenches after the rainy months, usually once in seven to ten days depending on weather conditions. In parts subject to cyclonic weather, propping is essential and this should be provided before the monsoon sets in or irrigation is given. In perennial banana plantations or on rainfed hilly areas, no irrigation is given to the crop, but in the former case water may be let into drainage trenches to reach the brim, so that the feeding zone of roots gets moistened through radial spread of moisture.

The bananas in some countries are irrigated at intervals of fifteen days from February to May and receive approximately 5 acre inches per turn. This procedure is adopted in plains where the annual rainfall is about 60 inches only.

In the opinion of Fawcett (46) "irrigation after flower forming will not affect the number of fruits in the bunches." Water channels close to the suckers are beneficial in the earlier stages of growth, but it is advisable to shift them a little away as the plants advance in growth, as proximity of water channels only encourages the production and growth of suckers which may not be desirable in cases where only the mother sucker or a few more are allowed to flower.

An experiment to determine the water requirement as well as to see the effect of ridge planting of banana was carried out at the Modibag gardens at Poona. Banana plants were planted on ridge with trenches opened by their side at a distance of three feet. The trenches were two feet deep. The following table shows the details of the performance of plants on the ridges as compared with that of plants in level beds by their side:—

Ridge vs. level planting of banana

System.	Average girth of plants in inches at base.	Average height of plants in ft. and inches.	Weight of fruit per bunch. lb. oz.	Number of fruits per bunch.	Total number of bunches harvested during the same period.
Flat bed	25	6-8	15-8	80	39
Ridges & trench	28	7-3	24-0	93	61

It will be seen from this table that the superiority of the trench and ridge system is established, although it requires a larger quantity of water. The actual quantity of water given in flat beds was 3·23 acre inches, while it was 3·30 acre inches in the trenches per irrigation turn. These trials were conducted with the *Walha* variety of bananas grown in medium black soil. On the light soils which are usually well drained, the bed system also works well but the frequency of irrigation has necessarily to be greater. It is noted that the interval of irrigation depends upon the nature of soil and weather conditions, and it can be adjusted to five to six days during summer and eight to ten days during the other seasons. In very light soils this interval may be of four days only.

The advantages of irrigating banana stools in trenches may briefly be summarised as follows:—

Advantages of trench irrigation

1. The average weight of fruits per bunch increases by about 55%.
2. The number of fruits per bunch increases by about 16%.
3. The plants grow and mature quicker, and a larger number of bunches can be harvested during the same period from an equal area than in flat beds.
4. Labour and water charges are low.
5. Damage due to fungus diseases is minimized.

Heavy irrigation encourages diseases

The banana plants are planted very close compared with most other fruit trees and whichever system of irrigation is adopted, it would practically amount to flooding the area. On ill-drained soils, heavy irrigation encourages the occurrence of the dreaded Panama disease caused by the fungus *Fusarium oxysporum* var. *cubense*, and the crown rot caused by *Fusarium moniliforme* var. *subglutinens*. However, the system of irrigating banana in trenches as explained above keeps the banana stools fairly above the level of water, unlike in flat beds, thus lessening damage due to these diseases.

The *Basrai* and the *Walha* are the chief commercial varieties of banana grown in the Deccan. Fruits of *Basrai* are sent to several parts of India including the Punjab and the North-West Frontier Provinces from the Khandesh districts and Bassein. The *Walha* is chiefly used for the local markets of the Poona district. From the market point of view, the Basrai is the better and superior type as its fruit is bigger and sweeter, though it is a poor keeper. A trial was conducted at the Ganeshkind Fruit Experiment Station, Kirkee, to find out the comparative economic value of these two varieties to the grower. It was found that the first bunch of *Basrai* gives higher yield than the *Walha* variety, other conditions being equal. As to whether in the long run the *Basrai* or the *Walha* will prove more economic to grow, is a subject yet under investigation.

Banana variety trials

The fruiting period in the banana varies in different varieties and seems to be considerably influenced by the quality and size of the suckers selected for planting as well as the climate. *Basrai* generally fruits in fourteen months. *Walha* requires about ten months, while *Velchi* and *Son Kel* take twelve months. The fruiting age from planting apparently is also closely related to the size and age of the suckers while planting. It is believed that the larger the suckers, the shorter is the fruiting age from planting. But in such cases the yield of fruits is generally less.

Fruiting of bananas

It has been reported that in the Godavari district of the Madras Presidency, bananas generally make the maximum growth during the rainy months of July to November and it takes nine to thirteen months to throw out bunches from the date of planting. Flat sided fruit varieties in general, seem to take a much longer time to bear fruits than the round fruited ones. The number of days taken from flowering to harvest of fruits varies widely, apparently depending upon the variety and season of flowering. Maximum production of the *Poovan* variety is noticed from December to March, of *Rasthali* from April to May, of Mauritius from October to November, and of hill bananas almost throughout the year. In Madras and Bombay bananas are generally available in local markets throughout the year, but June to October and December to March seem to be the two periods when trade is the busiest.

The number of hands per bunch and the number of fruits per hand are both varietal characters, but the early formed hands have been invariably found to record higher weight per fruit (74). It may be observed that ripening and rotting are processes that are hastened markedly when bunches are cut into hands than otherwise.

Suckers left to flower in a stool

In the case of *Basrai* and *Lal Kel*, only the sucker which is planted is allowed to flower in Bombay State. All side suckers are pruned off as soon as possible after they appear, in order to give better facilities of growth to the mother plant. In *Walha*, *Lal Velchi* and *Son Kel*, more side suckers are allowed to grow and flower. At Bassein and near Jalgaon, however, there is a tendency to have only the mother plant to flower in all varieties. Where only one sucker is allowed to flower and fruit as in the case of *Basrai*, the life of the plantation is limited to about eighteen months. In other cases, the plantation may be prolonged for several years, without being replanted, as sucker after sucker will be allowed to fruit in the same stool. In *Basrai* the later suckers are extremely poor yielders and hence the practice of allowing only the mother plant to fruit. The local practice in some parts of the Madras State is not to remove the suckers at all from the plantation when once it is raised and the crop is treated as a perennial one. Plantation of about a hundred years of age or over are not unknown even today. In perennial banana plantations in South India, the mother plant is cut after the harvest of its bunch, and suckers are allowed to bear the subsequent crop. This process is repeated year after year in the rich alluvial banks of Cauvery in Tanjore district. Planting banana after banana in the same land elsewhere undoubtedly leads to a progressive decrease in the yield of succeeding crops. Banana is, therefore, generally rotated with a cereal or other crop like cotton alternately in Bombay State.

In North India the usual practice is to remove all suckers till about 9 months after planting, when one good sucker is allowed to grow for producing the second harvest. Where leaves are marketed, more than one sucker may be left in ratoons, to follow on.

Fawcett (46) mentions that an attempt has been made

to develop new types of bananas by raising seedlings at Hope Gardens, Jamaica. But very little success seems to have been achieved in this work. It was further reported that an effort was made from 1922 to obtain a new variety of banana with commercial advantages of Gros Michel but immune to the Panama disease. This work involving a good deal of investigational effort relating to hybridization and seedling raising lasted for several years. Cheesman reports that he has obtained a hybrid seedling of Gros Michel and a seeded banana, which is highly resistant to the Panama disease.

Improvement of banana by hybridization

All edible varieties of banana are said to have been derived from the sub-genus *Eumusa*, which contains about twenty species. Cheesman (26) suggests that the species of *Eumusa* are likely to play an important part in the breeding of new varieties of bananas. Hybridization of banana has not been attempted so far in India. At the Ganeshkind Fruit Experiment Station, Kirkee, Poona, seedlings of *Sonkel Chanda* and *Nendra Bali* varieties have, however, been raised on a large scale, with a view to get new types of this fruit. The crop of seedlings has been tested for several years. Interesting variations have been recorded but no seedling gave a fruit superior to the existing commercial types, though some of them were better than the parent fruit. Hybridization of bananas may prove to be a valuable line of work in many parts of India, to secure a recombination of desirable characters from amongst the varieties already existing in the country and also to evolve varieties according to the regional needs. The standardization of existing varieties with a view to eliminate the inferior types, and restrict production to tracts where the cost of cultivation is the minimum and transport facilities are easily available, seems, however, to present equally important problems needing urgent attention in these parts (73).

It is difficult to generalize any statement relating to the cost of cultivation of bananas as it would evidently differ from tract to tract owing to labour, irrigation conditions, etc. The following statement, however, gives an idea of the cost of cultivation and total receipts realised from a plantation at the Modibag gardens during the years 1921-26. These figures are not intended to serve as a

Cost of cultivation

Items per acre.	1921-22.			1922-23.			1923-24.			1924-25.			1925-26.		
	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.
Cost of cultivation	488	2	0	342	8	0	341	4	0	341	4	0	341	4	0
Supervision charges	45	12	0	32	1	0	31	15	0	31	15	0	31	15	0
Marketing charges	14	3	6	9	8	0	9	8	0	9	10	0	12	8	0
Assessment of land	3	11	3	3	11	3	3	11	3	3	11	3	3	11	3
Interest @ 9% on the sum invested ..	49	10	0	35	0	0	34	14	0	34	14	0	35	2	0
	601	6	9	422	12	3	421	4	3	421	6	3	424	8	3
Value of the yield	1,202	13	6	1,422	10	0	953	6	0	965	4	0	1,252	0	3
Gain	601	6	9	999	13	9	532	1	9	543	13	9	827	8	0

basis for any economic calculation, as the receipts were realised by retailing on the spot for the *Walha* variety near a large city, and not by wholesale disposal as is usual with the growers in the villages. The changed economic conditions during World War II and subsequently, make it difficult to take these figures as anything except of comparative interest. (See page 24.)

Food value of banana

Banana is accepted in all respects as a fairly nutritious fruit. It is one of the cheapest fruits and in India, the rich and poor alike are fond of it and would take it daily whenever possible. There are some varieties which are more popular in the market as dessert fruit than others. Unripe banana is a very popular vegetable in many Indian homes. It is always consumed in the cooked state but if taken uncooked, it may cause digestive disturbances. The cooked vegetable is a good source of energy being fairly rich in starch; in this respect, it resembles root vegetables like potato and sweet potato. The chemical composition of some of the local varieties is given on pages 26 and 27.

According to Brooks (20), when bananas contain 5-10% sugar content and are heated to 50° or 60°C they retain this sugar, vitamin A, B_1, B_2 complex and C and protein contents. The loss in weight is 66%, which represents a considerable saving in transport. Four drying plants are said to be in operation in the Cameroons.

The Hawaiian bananas are stated to be a poor source of calcium but a good source of phosphorus. The cooking types of bananas are reported to be a better source of vitamins than the table varieties. All bananas, however, are found to be a good source of vitamin A and C, and a fair source of vitamins B_1 and G (B_2) in their ripe stage (68). Combined with milk, ripe bananas are also recommended in Hawaii for infant feeding, and as a reducing diet for the obese (68). Sugiura (86) states that banana contains fair amounts of vitamin A, C, and B complex. In the Philippines, some varieties are given to children as they are more easily digestible than other foods. Chevalier (35) states that an excellent cider may be made from bananas as good as, if not better than good French cider, and this can be sold at a cheap rate.

Average composition of the edible flesh of fruit according to Winton (94) is as below :—

Solids Total	Solids Insol.	Protein	Acid (Malic)	Invert sugar	Sucrose	Ash Total	Ash Alk.*
%	%	%	%	%	%	%	ml.
27·54	3·40	1·16	0·41	11·69	10·37	0·86	91

*Ml. 0·1 N acid per 100 gm. fruit.

Mottram and Graham (72) analyse banana as per table given below :—

Grammes per 100 grammes				mg. per 100 grammes								Acid base balance per 100 grammes
Protein	Available carbohydrate	Unavailable carbohydrate	Calories per 100 gms.	Na.	K.	Ca.	Mg.	Fe.	Cu.	P.	Cl.	c.c $\frac{N}{10}$ Alkali
1·1	19·2	3·4	83	1·0	348	6·8	41·9	0·41	0·16	28·1	78·5	79

Vitamins—International units per 100 gms.

A	B_1	C	Remarks
250-340	30	146-300	Moderate for C

Qualitative data on different contents is given by Daniel and Munsell (37) as follows :—

Food	Vit. A	Vit. B	Vit. C	Vit. D	Vit. G.	Year reported	Investigator
Banana ..	250	10-50	20	0	50	1933	Eddy
(*Musa sapientum*)	200	..	..	..	..	1933	Fraps and Treichler
	..	..	10	..	..	1922	Givens, Mc Cluggage and Van Horne

The figures represent Sherman Units per 100 grammes.

Component	*Sonkel.*	*Velchi.*	*Mutheli.*	*Rajeli.*	*Rasbali.*	*Walha.*	*Basrai.*
	%	%	%	%	%	%	%
Skin	14·00	13·00	15·82	13·99	23·00	20·30	32·55
Edible matter	86·00	87·00	84·18	56·01	77·00	79·70	67·45
Moisture	68·00	65·00	76·00	76·00	68·00	72·00	74·00
Reducing sugars	9·77	10·42	5·50	10·20	4·50	4·58	5·32
Non-reducing sugars ..	12·67	10·24	14·60	7·14	14·00	10·49	10·71
Total sugars	22·44	20·66	20·10	17·34	18·50	15·07	16·03

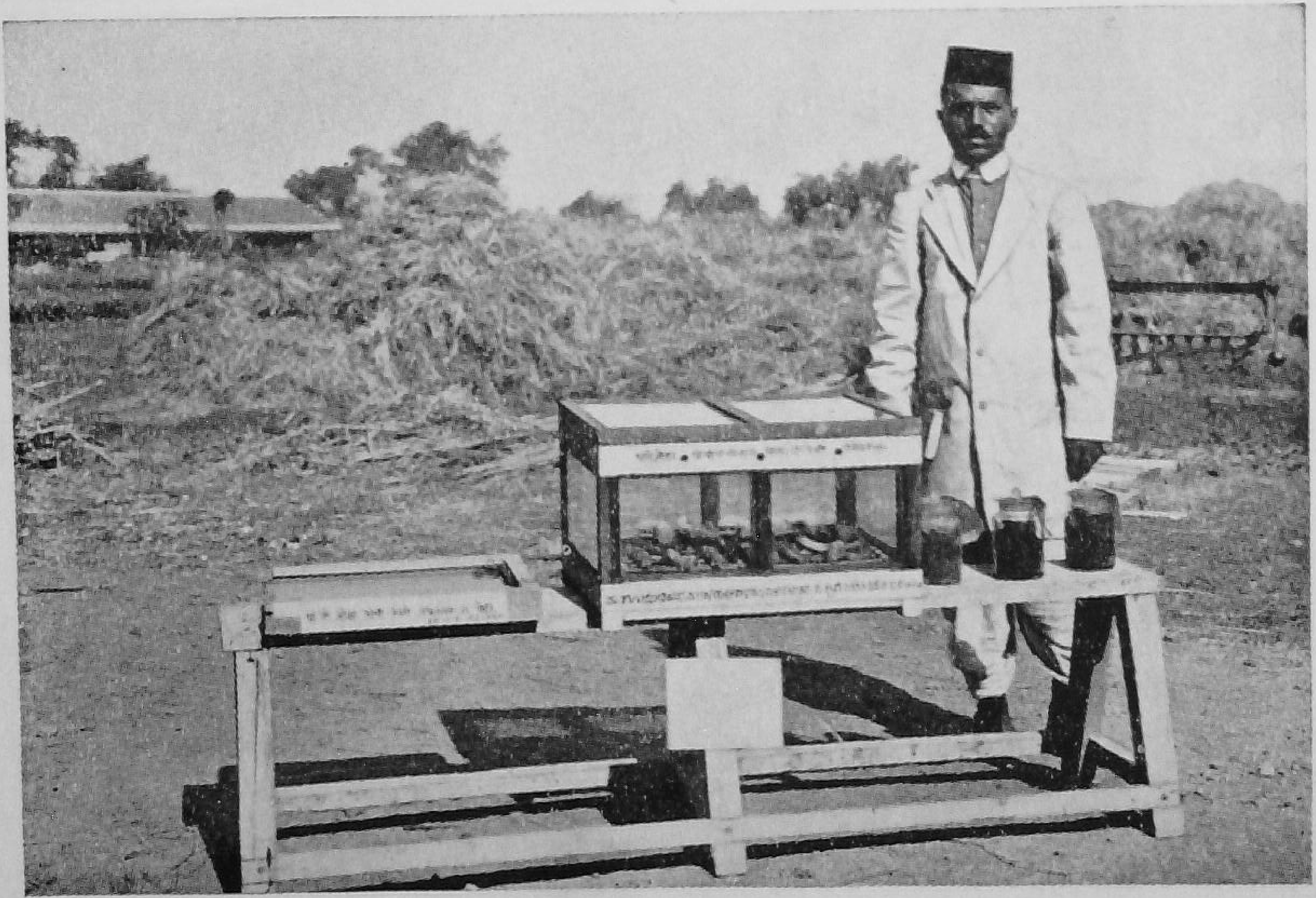
The ripe banana contains 18% to 20% of total sugars, partly as reducing sugar, and partly as saccharose. Bremond (19) describes successful experiments undertaken in Algeria in 1940 to determine satisfactory methods of making alcohol from bananas. Further experiments in 1941 in French Guinea were equally successful and factories were established, the potential output of each one of them being 10 hectolitres of motor spirit a day obtained from 120 to 150 quintals of raw material (1 quintal=100 kg.).

The fruit is used in a variety of ways. Besides the fresh fruit, banana can be dried and eaten as dried "figs." It is also used in fruit salads. Green raw banana is powdered after drying and used as flour.

An excellent preserve known as *Panchamrutam* is prepared out of bananas in the Palni temple of the Madras Presidency, and because of its reputation for quality there has sprung up a small trade at the place in this product. *Panchamrutam* under different local names is also a popular household dish in several banana growing areas in India.

Sun-drying

At Agashi and some other places on the Western coast of the Bombay Presidency, banana is dried for sale. It is estimated that about Rs. 5,000/- worth of dried banana finds sale in the market of the Bombay city annually. The only variety which gives an attractive dry product is the Bassein *Rajeli* as stated already. When dried, this variety assumes a beautiful yellow colour. The flesh is soft and sweet, with very little acidity. For drying well-developed fruits are plucked and stored in a heap till they are ripe and soft. The skin of *Rajeli* fruits assumes a perfectly black colour when fully ripe. At this stage, the skin of the fruit is peeled off, and the pulp is exposed to the sun. When properly dried, it assumes a golden yellow colour. The fruit takes about a week to ten days for complete drying. Low wooden platforms are prepared on which the fruit is dried. Sometimes when the drying is nearing its end, a little clarified butter (ghee) is smeared thinly on the fruit surface in order to brighten the colour. Other varieties of banana can also be dried in this manner, but the quality of the resulting product depends upon the percentage of sugar and moisture contents as well as upon the character of the variety chosen. Bananas are found to shrink to nearly



GLASS TOPPED CASE USED FOR SUN DRYING OF BANANAS IN ORDER TO SECURE HYGIENIC CONDITIONS FOR DRYING.

Facing page 28.

one-third of their original weight when dried. Insects and flies are drawn to drying fruits in large numbers and it is always desirable to cover the fruit while drying, with cheap mesh cloth fixed like mosquito curtains about a foot over the fruits. Glass boxes are also employed in this work, where insects abound and where the hot weather is of short duration. A simple case with glass sides and glass top can be used for this purpose. The box may be provided with several ventilator holes bored into its sides. The fruit is placed inside in a single layer, and the glass case develops inside a higher degree of heat than the outside atmosphere, and the fruit is dried quicker and much better than under the curtain. The fruit is also protected in this case from dust, insects and wind. The product thus prepared is sanitary. Glass cases as described above have been tried under Indian conditions but had to be given up as uneconomical for commercial use. Dried banana has a dull colour unless subjected to sulphur fumes after peeling and before drying in the sun. Sulphur fumes also check the damage by pests on the fruits. *Rajapuri* variety can also be utilised for drying, adopting more or less the same methods as those for *Rajeli*.

Drying of bananas in the sun becomes impossible in this country for the rainy season harvest. There is no sunshine in this season often for several days due to continuous rains and cloudy weather. During summer months, the frequent dust storms make sun-drying insanitary and hence undesirable. The fruit which is kept for drying falls a prey to several insects which thrive under the peculiarly congenial climatic conditions prevailing during the monsoon season. Owing to these difficulties, artificial drying of bananas has been attempted in wooden chambers. The apparatus consisted of two main parts detachable from one another, namely, the wooden drying chamber and the fire place or the hot air generator. The wooden chambers are double fold, and rest on one side of the generator. The generator consists of a cast iron body surrounded by a galvanised iron sheet jacket, which leaves an angular space of about six inches. This jacket has an opening at the bottom through which it draws fresh cooler air of the outside atmosphere to replace the original air which gets heated and escapes through the other opening of the jacket into the drying chamber. The current of hot air is thus kept continuous and the moisture in the

fruits is evaporated as they come into contact with the hot air current. The evaporator is kept slanting and the trays can slide in it. This position helps the utilisation of all the hot air and the speed of the rising hot air current is slowed down. The smoke of the fire does not enter the drying chambers and there is no risk of the fruit being discoloured and spoiled by it. Although the temperature of the chamber depends upon the nature of the fuel used, it is not difficult to maintain a uniform temperature in the chamber throughout the drying period by regulating the feeding of the fuel.

A smaller type of banana dehydrator has been devised at Kodur (Madras) with a special device for maintaining a uniform temperature without having to disturb the drying chamber. A metal case is provided over the oven and this is connected to the drying chamber. The case has two small apertures on the sides which can be conveniently kept open or closed by a movable shutter for regulating the intensity of heat. Good quality "figs" have been produced from some Madras banana varieties in this dehydrator within a period of eight hours as against four to five days taken by sun-drying.

The drying chamber previously mentioned has a length of 9 feet 7 inches, a breadth of 2 feet 4 inches, inside height of 1 foot 6 inches and is kept at a gradient of 2½ ft. while working. The trays used measure 2 feet in length internally and 2 feet 2 inches externally. Their breadth is 1 foot 5 inches and 1 foot 6 inches, respectively. The trays are about 2 inches deep. In all about 22 trays can be used at a time and they can be placed in two layers. The temperature of the evaporator is best maintained at about 115°F for proper drying. A higher temperature than this causes scorching of the fruits. A temperature of 120°F for nine hours is recommended in New South Wales for preparing banana figs in dehydrators (82). If banana "coffee" is to be prepared, the temperature is raised to 130°F after the figs are prepared. After eighteen hours of drying, the figs are roasted in a coffee roaster and ground in an ordinary coffee mill. The powder thus obtained is used in proportion of two teaspoonfuls in half a pint of water to which half a pint of milk and sugar to taste

are added later. Dehydration of bananas is likely to pay in the districts of North Kanara where proper transport facilities do not exist. Mr. P. G. Joshi, former Superintendent of the Ganeshkhind Botanical Gardens, Kirkee, reports that a London broker had tried his sun-dried banana sample and remarked that he had found them better than the Philippine and Canary Island products.

In countries where the climate is dry, ripe bananas are exposed to the sun till the skin begins to wrinkle, when they are peeled. The peeled fruit is then again further dried in the sun until crystals of sugar are formed on their surface. The dried product is then packed. This process is practicable in dry climates only. Another process is to ripen the fruit and then to cut it into four lengthwise pieces, and dry them in the sun on bamboo platforms. The product develops sugar crystals on the surface and keeps for several years. A third method is to boil the fruit in water to which a little gypsum (calcium sulphate) is added, and then to dry in the sun on bamboo platforms.

Gaton (48) discusses the value of banana flour as a food and compares it with other materials. He mentions "banana pommo", "Su" and "Sung Traw" as varieties of Indo-China which yield a good quality flour. Banana flour is prepared from fully mature but unripe fruits which are peeled after loosening the skin by blanching and sliced into $\frac{3}{16}$ inch thick slices which are fed on wooden trays and then exposed to sulphur fumes in a sulphur box for half an hour. They are then either dried in the sun under dust-proof conditions as far as possible or dehydrated in the home-drier at a temperature of 160°-165°F. The dried chips are then powdered in a ball mill to form a good powder. This is used as food when mixed with cereal flour.

Several important diseases and pests of this crop have been noticed in India. The important among them are the following:

Diseases and pests of banana

1. The Panama disease caused by *Fusarium oxysporum*, var. *cubense*.
2. The banana scab. *Gloeosporium musarum*.
3. The banana weevil (*Cosmopolites sordidus*).

The Panama disease occurs under a variety of conditions and is of great complexity. It is a wilt disease caused by the soil pathogen named above. The organism attacks the suckers and roots of the plants. The name Panama disease comes from the fact that the disease was first recorded in Panama in the year 1903 and a few years later it was found to play havoc in plantations of Panama and Costa Rica.

Panama disease

Considerable work has been done to check the Panama disease by breeding resistant varieties in the West Indies. The Gros Michel type of banana which is the chief table fruit produced in those islands for export to North European markets was found to be very susceptible. Finding that the fungicides were not effective in controlling this disease, breeding of resistant types was taken up at the Imperial College of Tropical Agriculture, Trinidad, in the year 1922. Since then a good deal of work has been done on this problem, and a banana strain named I. C. I. (Imperial College No. 1), which closely resembles the Gros Michel though possessing a few very minor defects, has been evolved. The work is being continued with a view to improving the I. C. I. strain further.

The following varieties in the Philippines are reported to be resistant to this disease:—

Sabe (*M. sapientum*, var. *compressa*).
Tennate or Gloria (*M. sapientum*, var. *Ternatensis*).
Bungulan (*M. sapientum* var. *suaveolens*).
Lacatan (*M. sapientum* var. *lacatan*).

Wardlaw reports that the Panama disease has been successfully controlled in Honduras by flooding and that infected fields flooded for six months have produced fruit for nearly six years with only sporadic outbreak of the disease.

During the last few years the Panama disease has also been noticed in parts of the Bombay State, *e.g.*, at the Aley village and round about Junnar in the Poona district. The trouble is now spreading to other areas also. The most susceptible variety is found to be the best table variety locally called the *Sonkel*. The chief symptoms of Panama noticed in this tract are that, when the

Occurrence and symptoms of Panama disease and its causes

plant comes to fruit the leaves begin to wither and the fruits do not develop. Leaves and suckers dry up. The fruit becomes useless if it matures at all. The disease affects the vascular tissues which become discoloured. The disease is attributed to the formation of a high subsoil water table or water-logging conditions of the soil and consequent lack of soil aeration and development of acidity in it. It also occurs in soils lacking humus. Very shallow soils appear to favour the disease. Prevention and remedial measures against this disease have not yet been worked out. The banana varieties are found to be resistant in varying degrees to this disease. A change of variety for planting, therefore, seems to be a possible step in preventing this trouble.

Preventive and remedial measures

The banana scab

This is a disease of the fruit and is caused by the fungus *Gloeosporium musarum* which develops on the fruit stalk. A reddish brown clour develops on the fruit and when closely observed, minute transverse markings are noticed. They develop into numerous longitudinal shallow cracks and turn black in colour. The skin begins to dry and turns greyish brown. The cracks grow larger and deeper. The pulp is also gradually affected, becomes dry and discoloured. Pustules on the affected skin contain spores. The remedy is to spray the bunches with Burgundy mixture (4 lb. copper sulphate, 5 lb. washing soda, 50 gallons water) before the disease is likely to appear.

Banana leaf spot is not common in India but the Bunchy Top is reported to have occurred in a few places. Removal of the affected plants and burning them is the only possible remedy.

Banana weevil

A weevil named *Cosmopolites sordidus* is seen to attack the banana rhizome in the Dharwar district and the Bassein area. The weevil spends its life in the banana rhizome but sometimes its damage may extend to the base of the stem. It is, therefore, difficult to deal with. Eggs are laid in the rhizome and dirty white grubs hatch out. The effective remedy is to remove and destroy the affected plants, and plant healthy suckers.

Very frequently the banana crop is damaged by low temperature. Being a succulent plant, the banana probably suffers from

frost more than several other plants. In the Northern and Central Divisions of the Bombay State, frost damage is considerable when it occurs. It is, therefore, necessary to devise economic methods to prevent the loss caused by frost. Modern orchard heaters such as those used in the United States of America and other Western countries are being examined here for their adaptability to this country. Raising of orchard temperature on nights when frost may be expected by burning heaps of fuel wood is found to be fairly satisfactory in our plantations. Locally made heaters are used with advantage. It requires 125 such heaters per acre to raise the temperature by 5°F over the surrounding atmospheric temperature.

Damage due to frost

In Queensland, it has been found that a bunch of banana completely enveloped in a bag affords not only more protection from frost and cold winds, but has other advantages, in that the fruit is superior in length and circumference and uniform in development and flavour. Bagging also prevents loss from sun scorching, splitting of fruit and ravages of caterpillars as well as spoiling by birds.

Bagging of bunches

The cost of the bags in the first instance is rather high, but most of them will last for a second use, and the higher price obtained for the bunches will more than cover the investment.

Grading and packing of bananas in accordance with known or accepted standards is unknown in the country. No special method of packing is practised. Whole bunches are carted to the market loose in bullock carts where the distance is not far. Hands are cut and packed in gunny bags or bamboo baskets for transport to long distances. Wagon loads of banana bunches are thus sent to the Punjab and other northern parts of India from Deccan. Whole bunches are wrapped in banana leaves and stowed on board the steamer for export to Basra and other places. Standardization of the methods of grading and packing this fruit is now largely practised in other countries growing banana, such as New South Wales and Cuba. Absence of standards of grading and packing gives rise to a number of malpractices and

Packing and grading of bananas for the market

adoption of standard methods of grading and packing would therefore be of great advantage.

It is essential to harvest the bunches at the proper stage of ripeness. The bunches should not be exposed to the sun as far as possible. The hands are separated from the main stem about twelve hours before packing. As much of the stem as possible is retained with the fingers lest the stem-ends blacken and the fruit loses flavour. For long shipments, boxes are found to be more suitable than bamboo baskets. Hangers will be better if they can be provided. In packing the fruit, the bunches are cut into three or four pieces and their inter-spaces are filled with single fruits. In grading, a high standard should be maintained and different sizes of fruits should be strictly packed and sold under different grades. Bananas exported from the Madras Presidency are booked in railway wagons without any packing, or with only a lining of banana leaves between every two layers of fruits.

Farringer (45) concluding his note on the outlook for the banana industry in the American tropics suggests that air transport may be instrumental in introducing some of the more delicate and perishable exotic varieties to north American consumers.

Clean bunches of banana are carried in special holds from the West Indies to the British Isles. In the Canary Islands the fruit is packed in crates made of the following pieces:

16 side pieces, each $\frac{5}{8}$" thick, $2\frac{1}{2}$" broad, and 26, 28, 30, 32, 34 or 36" long.
6 end pieces, each $\frac{1}{4}$" thick, $2\frac{1}{2}$" broad and 14" long.
4 head pieces, each $\frac{5}{8}$" thick, 22-27" long and $2\frac{1}{2}$" broad.
4 head pieces, each $\frac{5}{8}$" thick, 12-17" long and $2\frac{1}{2}$" broad.

—

30 pieces in all per crate.

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The Cavendish variety of banana which is the chief type grown in the Canary Islands has soft skin and, therefore, requires crates of the above description for packing for safe transport. The bunches are generally laid in with the stalk, while packing in the crates. High quality bunches are wrapped in cotton wool sheets before packing.

Maize husk is also often used for packing fruits for shipment. The insulating and absorbing qualities of this packing material together with efficient ventilation of the fruit during shipment assure safer conditions of transport than those of cold storage. Eastwood (44) advocates packing in hands or clusters instead of the prevailing method of packing in singles in New South Wales. In the Gold Coast tract the Canary type of banana is packed with paper bags round the bunches (22). This system is found very convenient and economical. Bunches are harvested within twenty-four hours before shipment. Cut stalks are smeared with vaseline on trimming before shipment. Gregory (50) of Queensland recommends that the following instructions may be carefully followed while handling fruits for packing:—

1. Select only mature fruits.
2. Avoid bending of the shanks of bananas when removing the bunch from the plant and transporting it to the packing house.
3. Keep bunches in a vertical position.
4. Pack in good case of timber with thick sides to get maximum protection in transit.
5. Keep fruit cold during summer when harvesting and transporting. In winter keep the fruit from being chilled by protecting it from cold winds.
6. Clean fruit of all foreign and decayed matter.

The banana packing case should be made of good timber free from knots. The end should be $\frac{3}{4}''$ thick and where cleats are used these should be $2''$ wide and $\frac{3}{8}''$ thick.

In Queensland the bananas are graded into sixes, sevens, eights, etc., according to the length and thickness of the fruits. Sweating before packing is also practised in some countries. The fruits are stored for 24-30 hours before packing. This helps them to keep long and stand transport better. While packing, fruits are packed in layers and different methods such as "single pack", "single alternate pack", "vertical two pack", etc., are adopted. Of these methods, the "full hand pack" and the "part hand pack" are considered the best.

In transporting the fruit to longer distances, it is advisable to select only well developed green bunches, because ripe fruits decay and a great loss might occur subsequently. For long distances, fruit is packed raw and ripened artificially.

Artificial ripening of banana fruits

Banana is ripened in some countries by the aid of gas heaters, the bunches being staked in specially constructed rooms. As some accelerating agent is necessary to ripen the fruit successfully, it is thought that this is provided by the ethylene gas. It is recommended that coal gas be used instead, a concentration of one part per thousand having been found sufficient in reasonably air tight rooms in the summer. The optimum conditions for ripening bunches are 68°F temperature, and 85% humidity to the "spring stage" followed by 70%, and in winter 85% to the "colour show" stage followed by 70%. Temperature of 75°F to 80°F for ripening the banana in air tight chambers is good. The period taken for ripening varies from six to forty-eight hours. In the Canary Islands the green fruit is exported just when it requires about 20 days to ripen. The bunches for export comprise eight hands in the minimum. Smaller bunches are said to be useless for export.

At some places in the Deccan (Bombay State), banana hands are heaped one over the other, covered with straw and mud and then smoke is blown into the heap. The green fruits change their colour due to high temperature thus generated. Ordinarily, atmospheric temperature in Western India is fairly high throughout the year, and therefore, it is not considered necessary to adopt artificial ripening processes for this fruit in this region. The most favourable temperature for successful ripening was found by Chona (36) to be 15°C to 20°C. The temperature in the curing pit during the summer months in the Punjab ranged from 35°C to 40°C. The pits provide no check on the growth of various disease organisms. By practical experience it has been found that banana and oranges cannot profitably be sent in the same hold. Emanations given out from oranges effect premature ripening of bananas and, therefore, it is necessary to have separate storage for citrus fruits and bananas.

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CHAPTER II

MANGO

(*Mangifera indica L.*)

"It will be hard to think of a fruit which has appealed to the people of this country to a greater measure than the mango. From the point of view of acreage and production, mango is easily the most outstanding of all Indian fruits. The adaptability of this fruit to a very wide range of climatic and soil conditions, the relatively hardy nature of the tree, the low cost of its culture and maintenance, and above all, its healthful dietetic qualities and its universal popularity as one of the choicest of the table fruits have contributed to accord the premier place to the mango practically in every nook and corner of this country" (98).

The United Provinces is the leading mango producing region of India, and produces about 3,300,000 tons of mangoes annually from an area of about 1,322,656 acres. The rapid extension of acreage under mango in the Bombay Presidency from 10,455 acres in the year 1920 to 27,701 acres in 1947 is a strong evidence in support of the fact that this fruit is increasingly catching the imagination of the progressive cultivator. The efforts to explore European markets for the Alphonso fruits made in the early thirties stimulated interest in this fruit and have encouraged growers and traders to invest capital in it. New area is being planted and new methods of packing and marketing the fruits are being tried.

Mango is at present one of the most important fruit crops in the Bombay Presidency. The total acreage under this crop is the highest, save banana. This area is spread in two chief tracts, namely, all along the western coast touching the Arabian Sea from the North Kanara district in the South to the Gujerat districts in the North, and in the Malnad and transition tracts extending from Dharwar to the Nasik district. The area under mango in other districts is comparatively small and scattered. From these facts it will be seen that mango production is a fairly large sized industry in this Presidency. The coastal tract com-

monly known as Konkan is renowned for mangoes of a quality, equal if not superior to any produced in any other country in the world. The soil and climate of this tract are extremely well suited to the cultivation of mango. Mangoes from this area have naturally established their own reputation and command a distinct premium in the markets of some parts of India and abroad. Other parts of the Presidency do produce considerable mango crop, but the fruit is mostly meant for local markets.

The mango is now grown in almost all the tropical and subtropical climates. Its original home is believed to be some-

History

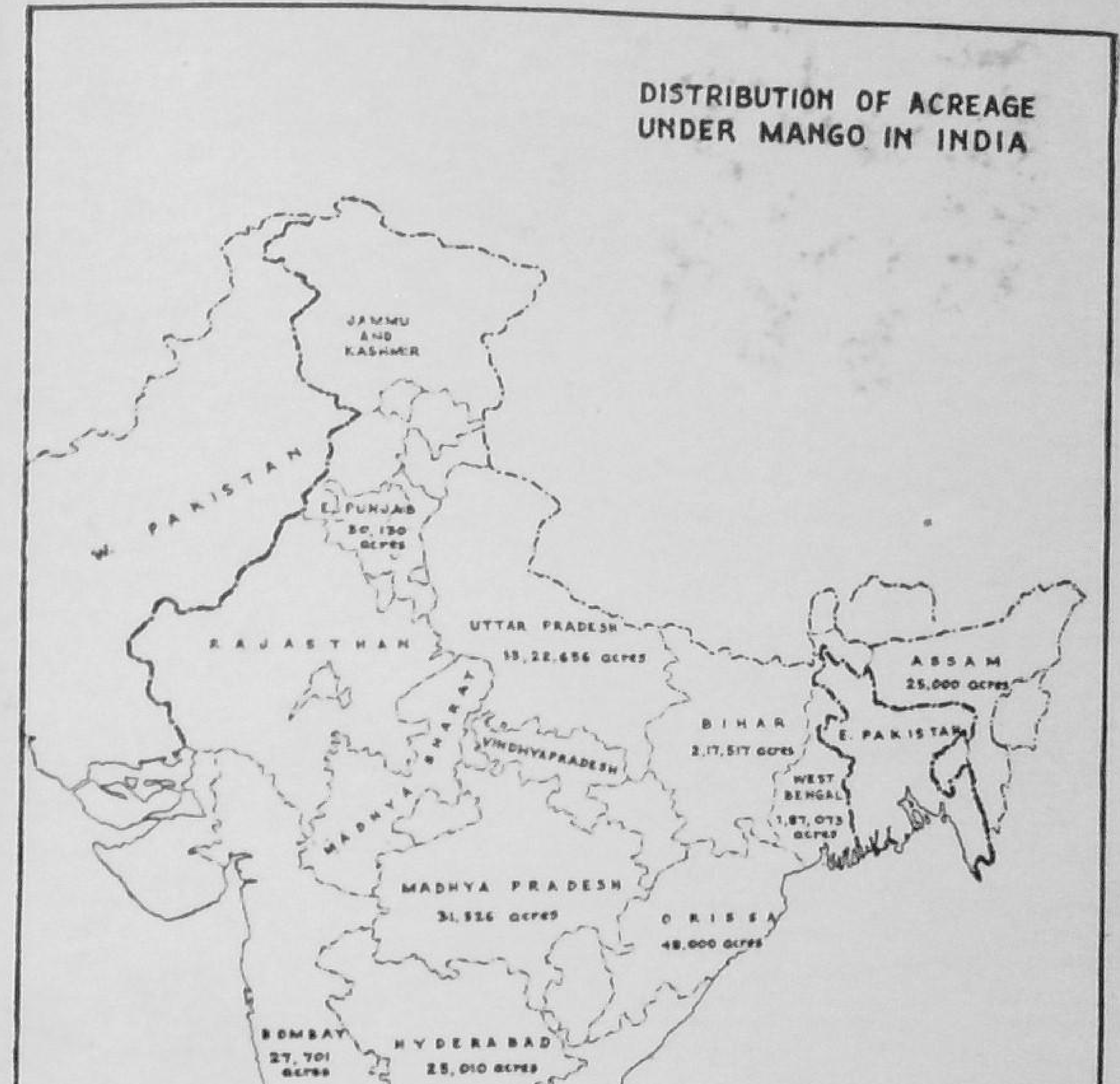
where in Eastern India and Malayan Archipelago. Its numerous varieties have so early—indeed prehistorically—disseminated to other parts of India, that it is found difficult to trace the origin of mango to a more restricted region. From the evidence so far available it would appear that the monoembryonic mango has probably originated in some parts of India, but the polyembryonic types or races have their origin somewhere in Malaya.

Regarding the age-long appreciation of mango, it is enough to record here, the innumerable references to the diaries of travellers from the Chinese Hiowan-Thsang (632 A.D.) to Pirard who travelled in India in the early parts of the seventeenth century. A good deal of prominence is given to this fruit and consequently to the tree and its leaves in Indian religious ceremonies. Further, several hundred horticultural varieties of varied descriptions and local importance existing in all parts of India go to prove the remote antiquity of this fruit in this country. Huge seedling mango trees, a hundred to two hundred years old are not uncommon in almost all parts of India.

In India the chief mango provinces are :

MANGO ACREAGE

U. P.	1,322,656	acres	E. Punjab	30,130	acres
Madras	250,900	,,	Bombay	27,701	,,
Bihar	217,517	,,	Mysore	26,720	,,
W. Bengal	187,073	,,	Hyderabad (Dn.)	25,010	,,
Orissa	48,000	,,	Assam	25,000	,,
Madhya Pradesh	31,526	,,	Total	2,192,233	acres



DISTRIBUTION OF ACREAGE UNDER MANGO IN INDIA
JAMMU AND KASHMIR
W. PAKISTAN
E. PUNJAB 30,130 acres
UTTAR PRADESH 13,22,656 acres
RAJASTHAN
MADHYA BHARAT
VINDHYA PRADESH
BIHAR 2,17,517 acres
ASSAM 25,000 acres
E. PAKISTAN
WEST BENGAL 1,87,073 acres
MADHYA PRADESH 31,526 acres
ORISSA 48,000 acres
BOMBAY 27,701 acres
HYDERABAD 25,010 acres
MADRAS 2,30,900 acres
MYSORE 26,720 acres
T.&C. UNION
PERCENTAGE
10
20
30
40
50
60
U.P.
MADRAS
BIHAR
W. BENGAL
ORISSA
M. PRADESH
E. PUNJAB
BOMBAY
MYSORE
HYDERABAD
ASSAM
TOTAL ACREAGE IN INDIA 21,92,233 acres

The total area under mango in this country is 21,92,308 acres (1947-48). The area at present planted to mango has been the result of spontaneous effort of the appreciating grower and has by no means reached its limits. It would appear, therefore, that there exists a very wide scope for the expansion of mango cultivation and subsequent development of the mango industry in this vast country, provided the educated public realise its commercial possibilities and the activities of the various Agricultural Departments are properly directed. The existence of a large number of seedling trees of varied description and quality and grafted varieties of mango with numerous highly appreciated types will only assist such expansion.

Distribution

"The present confusion in classification as to groups and varieties of mango is so great that although considerable interest is being shown in the work, a long period will be required before a satisfactory adjustment is reached." So said Kinmen (79) of the Porto Rico Agricultural Experiment Station in 1918. These remarks are perhaps as true today as they were over three decades ago. Several sporadic and abortive attempts have been made to group together available varieties of mango in all mango growing parts of the world, but nothing tangible seems to have been yet evolved. The large number of varied seedling types, the multiplicity of soil and climatic conditions under which they grow, the innumerable regional names and synonyms prevailing for the varieties; the wide variations in their fruiting seasons and the long distances that divide the mango growing regions of the world make it almost impossible to collect together at one place and time all or even a large majority of the so called mango varieties for purposes of accurate description, proper comparison and correct classification. The few attempts made towards this end are neither exhaustive nor comprehensive enough to be linked together. As one of the best fruits on the surface of the globe, the mango ought to have received long ago a much more serious attention and strenuous effort of the systematic pomologist than it has hitherto done. It is hoped that it will not be long before this fruit is classified on natural lines and standard varieties are established.

In this connection it is gratifying to observe that the Indian

Council of Agricultural Research is devoting attention to evolving a system to classify the large number of Indian mango varieties by proper description supported by charts and true to colour drawings. A monograph on "Classification and Nomenclature of South Indian Mangoes" has been published recently by the Madras Department of Agriculture (Supdt., Govt. Press, Madras, 1950). Valuable material has also been collected on this subject at Baroda and elsewhere, and nation-wide endeavour to collate and codify these is necessary.

The erstwhile method of designating varieties solely on the basis of fruit description collected mostly from one locality has been replaced by a more rational description of all essential parts of the tree under diverse conditions of growth. These investigations have brought to light, that the fruit forms but one of the vast number of indices for identification of varieties; and this leads to the hope that evolution of a practical key for natural classification of our horticultural varieties of mangoes based on a number of important vegetative and fruit characteristics during the various stages of the growth of the plant is within the realm of possibility. One such key has been suggested by Naik and Gangolly for south Indian mangoes in the monograph referred to above.

Varieties of mango which are well known and valued in various parts of India are many. They are named after great men, seasons in which they ripen, colour, flavour, and various other factors. These names are often synonyms. Some of the varieties have local importance while others are known to the trade. Some of the important varieties of India are given below:—

Punjab	*Langra*, and seedling types.
Western United Provinces	Bombay (green and yellow), *Fazli* and *Langra*.
Central United Provinces	*Safeda*, *Dasheri*, *Khasulkhas*, *Samarbehist* and *Langra*.
Eastern United Provinces and Bihar	*Langra*, *Zardalu*, *Fazli*, *Gulab Khas*, *Bombay* (green and yellow).
Bengal	*Malda*, *Shadivala*, *Pulihora* and seedling types.

Bombay and Goa	*Alphonso, Mankurad, Fernandin, Maldez, Bishop, Musherad* and *Mulgoa.*
Northern Circars	*Jehangir, Himayuddin, Banganapalli, Chinna Suvarnarekha* and juicy varieties.
West Coast	*Olour, Mundappa, Neelum, Alphonso* and *Pairi.*
Central Madras	*Neelum, Bangalora, Baneshan, Rumani, Mulgoa* and *Alampur Baneshan.*
Southern Madras including Salem	*Neelum, Alphonso, Pairi* and seedling off-season bearing types.
Mysore	*Badami, Raspuri* and *Totapuri.*
Baroda	*Alphonso, Rajapuri, Jamadar, Salebhoy, Amdi* and *Vanraj.*

In the Presidency of Bombay, the Alphonso and Pairi are the most popular varieties of commercial importance. Due to its superior taste, colour, medium size and keeping quality, the Alphonso which is considered to be the best Indian mango, has spread under cultivation in various parts of India like Madras and the Hyderabad regions also. Other varieties such as the *Batli, Shendrya* and *Kala Ishad* are also well-known. The *Cowasji Patel, Khus, Amin* and others are fruits of large size with pulp of good texture, mostly used for pickles and preserves.

Soil

Mango trees are seen to grow well in a variety of soils from the well drained laterite soils of Ratnagiri, Goa and Belgaum and the medium black soils of Thana, Surat, Poona and Satara to the heavy deep black soils of the Sholapur and Bijapur districts. That the mango is among the least fastidious of fruit trees regarding soil conditions is further evinced from the fact that luxuriant plantations are to be found in the fertile Indo-Gangetic alluvial loams of the United Provinces, Bihar and Bengal, the Deltaic paddy lands of the north-eastern part of India, and the poor, rocky, light loamy soils of the hilly and lower mountainous region. There are huge old mango trees near Nasik and Khed Shivapur in the Poona district growing in medium black soils. Trees growing in the heavier soils of the eastern districts are not so large, nor do they stand comparison with the sky-scraping wide spread trees

of the Western Ghats. While moisture in the soil and humidity in the atmosphere promote the healthy vegetative growth as well as fruiting of mango trees in any kind of soil, a well drained fairly deep loamy soil is generally conducive to their best performance. The fruit borne by trees standing in sandy soil is reported to be "decidedly of inferior quality, watery and insipid" (92). Soils with a hard substratum or marl are also not good as they hinder the proper penetration and development of roots.

Temperature

Being essentially tropical, the mango tree cannot stand severe cold and frost conditions. A hot period is necessary for the development of the fruit. Mango blossoms generally appear during December to March, and any frost occurring during this period, as it often does, in sub-tropical and temperate regions, proves disastrous to the mango crop. The young plants and tender shoots and inflorescences of larger trees are killed by frost. In such tracts, however, "imported plants of mango seem to suffer most from cold than those raised from seeds in the country" (25). Although certain varieties seem to be more resistant to frost than others, stronger and healthier plants, in general, resist frost more than the weaker ones.

Rainfall

Rainfall during the blossoming season is highly detrimental to the crop. Rains injure the stigma, wash the pollen away and cause it to remain damp. Rains also develop conditions which encourage the powdery mildew and other diseases. The mechanical injury to the unprotected pistil is great. Much harm is caused to the mango crop even by prolonged cloudy weather during the flowering and fruit-setting period, as it encourages the flower-destroying fungus and the jassid hoppers. In tracts where late anti-monsoon rains damage the mango blossom, as in the Eastern districts of the Bombay Presidency, low yields and crop failure are perhaps much more common than in the Konkan and the transition tracts, where a dry period prevails at the time. Not only rains, but even excessive dew is apt to wash away the pollen grains depriving the pistils of their chance to be fertilized. Gunaratnum (61) observes that in Ceylon mango can grow in the dry zone with little or no irrigation with a rainfall of 25 to 75 inches

PREPARATION OF CHARCOAL BY FELLING OLD SEEDLING MANGO TREES OF INFERIOR MANGO VARIETIES.

Facing page 51.

per annum and on lands from 300 feet below sea level to 1000 feet above sea level.

In tracts subject to heavy precipitation as the West coast of India, some damage is also caused by early rains to mature fruits, and as a result it is found that the growing of the late varieties is a very precarious venture. Even in other areas, unexpected heavy showers may cause enormous fruit drops and serious loss to the growers.

A fairly high percentage of moisture in the soil is essential for the well-being of the mango tree, because in general practice it is not irrigated, but depends upon natural precipitation after it comes to bearing. Economically, therefore, the mango thrives best in regions where the annual rainfall is above thirty inches and even up to one hundred and fifty inches or more, provided there is no rainfall during the flowering and fruiting season. These conditions prevail in the Western parts of the Bombay Presidency, where mango thrives to its best. In drier tracts, however, the mango tree does well with irrigation. In the Madras Presidency, although the rains occur for a much longer period than in Bombay, they do not cause any damage to the mango trees, as the rains do not occur during the flowering and fruiting periods.

Altitude

Although the mango tree can grow from the sea coast upto a height of about 4,000 feet, it crops well only up to a height of about 2,000 feet if other conditions are favourable. Fernandez (46) states that any climate in Brazil in which the temperature does not fall below 0°C will suit mangoes. It is at its best in well drained, alluvial soils and in cool, sandy clay soils rich in humus and this especially refers to fruit quality.

Variations in seedlings

In raising a mango plantation, the rootstock may play an important part. Under natural conditions, the mango multiplies itself by seeds. In some parts of India, certain well-known varieties of mango are propagated by seed even now. It is not generally realised that seedlings of monoembryonic mangoes do not come true to type. Popenoe (122) writing about the mangoes of Cuba and obviously referring to polyembryonic mangoes observes: "It has long been recognised in certain parts of the Tropics that many seedling mangoes come more or less true

to type, when propagated from seeds and because of this fact the natives have learnt to recognise certain of the best defined types and have distinguished them with varietal names." He adds further that "We must admit the possibility for the time being that occasionally it may depart from the type perhaps because of cross pollination, perhaps because of some other cause." On the phenomenon of polyembryony, Popenoe quotes Belling of the Florida Experiment Station (1908), "the embryos arose as minute vegetative buds in the nuclear tissue surrounding the egg shell." Webber (186) from an examination of the Peach mango in the Transvaal considers that the degree of apogamy is about 100 per cent. and that the testing of the degree of apogamy in valuable mango varieties would be worthwhile before resorting to vegetative propagation, as seedling propagation is cheaper. Wester (189) remarks that the types of mangoes grown in the Philippines are all polyembryonic and therefore reproduce their special characteristics to a remarkable degree. He also states that the progeny of the monoembryonic types of India is variable. Horn (71) mentions that polyembryony in mangoes was studied in Porto Rico also.

Till recently all the Indian varieties of mango were considered as monoembryonic and hence, as a rule, they were thought not to come true to type. Recently about a dozen polyembryonic varieties of mango have been isolated in the region on the West coast of India by one of the authors, and as many as five seedlings per seed have been obtained and successfully planted. Over 30,000 acres under mangoes in Malabar and parts of South Kanara districts are planted to seedling mangoes. Since the trees are known to reproduce the parental characters to a high degree in these parts, it is inferred that this character is due to polyembryony. Some of the isolated varieties are reputed to bear fruits three to four years after sowing and have been found to reproduce the parental characters completely like all of other propagated trees.

Hartless (64) affirms that the mango is predominantly anemophilous. Burns and Prayag (25) record their observations that the mango flower is entomophilous and designed for short tongued insect visitors. Popenoe (123) also considers it as "truly entomophilous" and in discussing the

characters of the mango flowers, he remarks that it is entitled to be placed in Muller's biological class A, or flowers with freely exposed honey.

While self-pollination in mangoes is recorded as possible, the transfer of pollen to the stigma does not seem to be accomplished easily without the intervention of an external agency in spite of the close proximity of the organs. "Both the stamen and the pistil retain an erect position throughout and the pollen, as it is shed, usually falls upon the base of the ovary or the disc rather than upon the stigma"(25).

Wide variations in the nature of the fruits produced as well as in the vegetative characters of the seedling trees are recorded as a result of an experiment carried out at the Ganeshkhind Fruit Experiment Station, Kirkee and the Modibag garden, Poona during the course of over a decade for the purpose of collecting data as to whether mango seedlings come true to type or not. In this experiment, seedlings were raised from stones collected from the same individual parent trees and were allowed to bear fruit under uniform conditions. It was noticed that the vegetative habits of these seedling trees varied to some degree, but the fruit characters displayed wide differences in the size, shape, flavour and consistency of pulp, stringiness, etc. It is thus established beyond doubt that mango seedlings of the monoembryonic group vary from the parent tree both in vegetative as well as in reproductive characters.

Despite the variation in seedlings, it must be admitted that modern mango growing industry owes a great deal to seed propagation for the production of the choicest of our present day collection of grafted mango varieties. The origin of all the present commercial varieties of mango has been invariably due to chance occurrence of seedling trees in nature. When the high quality of the fruits of these seedling trees became known, mango enthusiasts took grafts from such trees, and thus the original individual was multiplied vegetatively until it attained a recognised status of a commercial variety. This is how the famous Alphonso, *Langra*, *Pairi*, and other varieties have spread under cultivation for more than a century. The *Samarbehist Chaunsa* of the United Provinces, the *Chinna Suvarnarekha*, *Jehangir* and *Himayuddin* of the Northern Circars and

Mundappa of the Malabar coast as well as the *Rajapuri* of Gujerat and the *Jamadar* and *Salebhoy Amdi* of Saurastra, are some of the varieties which have become most popular in their respective tracts during the last two or three decades, having been originally propagated from single individual seedling trees. The original seedling trees of *Chinna Suvarnarekha* and *Mundappa* are alive to this day and serve as a source of great interest to thousands of growers who cultivate these varieties. Similar is the case of the *Borsha* mango of Khandesh in the Bombay Presidency, the original *Borsha* tree which is over three hundred years of age, being alive in huge dimensions to this date.

Asexual methods of propagation are, however, necessary in the case of commercial culture of most mangoes. Although several workers report to have found it possible to propagate mangoes from cuttings, layering and gooty (marcotte), the method adopted in general practice in India for the propagation of superior varieties of mango is grafting on seedling rootstocks by the simple approach method and is known as enarching. Recently a number of workers have pointed out that cuttings of woody plants, if treated with growth-promoting substances strike roots readily. Girdling the shoots is also known to promote root growth and a few mango plants have been successfully raised from girdled shoots at the Kodur fruit research station, Madras. Cooper (33) has pointed out that some root forming substance in the plant is transported downward in the phloem and impeded by the girdling operation. If the girdled shoots are treated with heteroauxin solution, the number of roots per shoot is increased. He suggests that the heteroauxin accelerates the downward movement of a substance called Rhizocaline, which is necessary to root formation. The use of seedling rootstock, however, is found to be more economic and profitable than the use of cuttings on account of the long time taken by cuttings to strike roots, the low percentage of success and the weak root system formed by this asexual method.

Vegetative methods of propagation

Rolf's (146) remarks in this connection are worth noting. He observes that "if one has thoroughly ripened healthy mango wood, it is possible to strike cuttings with the help of ordinary green house appliances. The cuttings are made in the usual

way and struck in the ordinary bench, with bottom heat. If sharp sand is employed in the bench, the cuttings should be removed to pots when they have struck roots." Discussing the advantages of making rings on mature branches prior to preparing the cuttings, he adds "many of the cuttings made in this way struck readily enough, but the root system was weak. On this account, this method is less desirable for propagation than the use of seedling stock." Burns and Prayag (25) state that they could not make cuttings strike roots. They were successful in having some plants by layering and marcotte, but they do not recommend these methods to be preferred to grafting, owing to the difficulties mentioned above. Budding is done when the rootstock is in active growth, exhibited by the emergence of new flush of leaves. In Florida the operation is done normally in May or June while the months June, July and August have proved successful in most parts of India.

The method of grafting most commonly adopted here is enarching (or inarching), because of the simplicity of the operation, the ease with which it can be carried out, and the high percentage of success attained. Side grafting is practised in humid climates with considerable success. Other methods such as tongue-grafting are less frequently adopted under divergent circumstances with some success in different tracts. Cleft-grafting is now being employed on some scale in Ceylon on young and about three month old rootstocks. Budding of mango has been done with success at Poona, Madras and in the Punjab adopting the modified Forkert method, but it is not yet adopted by nurserymen as a commercial practice as in Ceylon. For enarching, seedling rootstocks are first raised in pots of suitable size. The pots employed in the Bombay Presidency are generally conical, 8-10 inches or more high and about 6 inches in diameter at the top. The base is narrow. These pots are specially prepared for nursery use only. They have the advantage of permitting the removal of the plant raised in them without breaking the ball of earth and without disturbing the roots while transplanting later on. The pots are not generally used more than once. Round pots called *madkis*, are also used. The conical pots are called *kundis*. *Madkis* are cheaper in price, help the soil to retain moisture and remain cool for a longer time than the *kundis*. Both are types of rough earthen pots. These

pots should be well baked in the potter's furnace before use which is identified by the metallic sound produced when they are tapped. If the pots are not baked well, they break easily.

A few nurserymen in the South Kanara district prepare containers made of hill grass twists, knit together into the form of a pot. Such grass containers, besides being cheap and light, afford no room for root injury at the time of potting. In Ceylon and the West coast of India, bamboo pots cut into a suitable size with drainage holes as in earthen pots, are also used at times. Bamboo baskets, that are so popular with coffee planters in South India are used occasionally for raising mango seedlings.

When the pot is selected, a small hole about one inch in diameter is bored at its bottom. This hole permits free drainage. It is protected from being choked with soil by placing a few pieces of pot-sherds with their concave sides facing it (48). On them are put a few dry leaves, coir or rags as a further measure of drainage protection. These dry leaves, coir or rags are not meant to serve the purpose of manure or to supply nutrients to the pot plants. When the pot is thus ready, it is filled with a mixture of the following composition:

Compost for filling pots

> Two parts of alluvium or ordinary surface soil, one part of sand or brick powder and two parts of leaf mould
>
> or
>
> Eight parts of leaf mould, eight parts of red earth and one part of sand.

Various other formulæ are also being adopted for preparing a good pot mixture. Whichever mixture is used, the underlying principle seems to be to have a medium of loose composition, so that there is as little risk as possible of breaking the tender roots of the seedlings in the process of what is called pricking out. This compost should also be rich enough to provide adequate nutrients to the young plants in the limited space.

Generally, where a large number of pots is prepared every year for sowing mango stones, a free supply of alluvial soil, leaf mould and sand is stocked in advance of the sowing season. The sand and leaf mould are properly sieved to remove the larger

pieces which do not give a uniform consistency to the mixture. They are mixed as required for use during the season. Filling of the pots with mixture is done upto about an inch from the rim. This space in the pots is essential in order to hold water. It is not necessary to provide holes for drainage when baskets are used.

Sowing of mango stones

Sowing of mango stones (mango seeds are popularly called stones on account of their hard seed-coat) then follows. It is found highly desirable to select good stones for this purpose. Stones should be fresh for satisfactory germination. They retain their viability under ordinary conditions for a few weeks only. In India stones of country or seedling types, which are prolific bearers, are preferred to those of superior table varieties for raising root-stocks. They should be plump, well developed and healthy. For this purpose, fruits are left to remain on the trees for a long time until they are fully ripe. They are then harvested and allowed to rot. The stones are then extracted. They are further graded and the heavier ones are generally used for sowing. Heavier stones are commonly believed to produce more vigorous and stronger seedlings than lighter ones. Two or three selected stones are sown in each pot, not more than an inch deep. Sowing is done nearer the side of the pot than in the centre. The soil is well pressed and copiously irrigated after sowing is done. In several parts of India, particularly in the South, mango stones are sown in well prepared nursery beds. If care is taken to lift the seedlings when they are not over about eight months of age with a ball of earth round the roots, and to pot them in a season when atmospheric humidity is high, the casualties are negligible. In Gujerat mango seedlings raised in nursery beds are potted when they are a year old. Their long tap roots are cut back suitably while potting, which is done in the rainy season. The cheapness of the method of growing seedlings in beds as well as the more vigorous growth made in the beds than in the pots, are responsible for the wide popularity which this practice enjoys among nurserymen. In some parts of Bihar, the stones are dumped together in a heap with a thin layer of soil thrown over them. During the monsoon, the stones germinate and as a result of overcrowding, though the seedlings grow to a considerable size, they get very weak and appear unhealthy. These seedlings are potted carefully, one or two months after germination.

The successful transplantation of seedlings depends upon the kind of tap root produced by the plant in the seed-bed. If the growing root meets with impediments, it changes its course, producing ultimately a very crooked root. To encourage a straight tap root, it is essential that the seed bed is prepared with great care and is rendered free from any hard clod of soil or other extraneous matter. It has also been found experimentally that sowing of stones with plumule up leads to the development of a straighter stem and tap root than the common practice of sowing the stones flat. Sowing of shelled stones, a practice recommended in Malaya, Philippines, Ceylon, Hawaii and North America has not proved satisfactory in this country. It may have a value only where due to wide-spread weevil infestation, careful sorting out of sound seed after shelling, becomes necessary.

Self-sown seedlings of mango are also often collected and transplanted in pots for rootstock purposes. As the mango seedling is sensitive to root disturbances, many of them may die under careless handling. In Hawaii, seed selection is done from fruits obtained in the mid-fruiting season.

Mango stone may germinate in about a month from sowing. As most of the Indian varieties are monoembryonic, each stone gives rise to a single seedling. If more than one shoot is seen to come up from the same stone from such types, it may be inferred that they are all branches springing from below the soil surface. They all have a single root system. In about two months, when the foliage of the tender seedlings turns green, all the weaker shoots should be clipped off and weaker seedlings rogued out, and only one strong seedling left to grow in the pot.

The pots with seedlings are all kept in rows in particularly shady places to enable them to grow well. If kept in full exposure to the sun, the seedlings become stunted and take a long time to gain height. Once a fortnight or so, the soil in the pots is usually stirred and a small quantity of liquid manure is added to it. The liquid manure may be prepared as follows :—

Manuring and stirring of soil in pots

1. Dissolve a handful of sulphate of ammonia in a bucket (about $2\frac{1}{2}$ gallons) of water

or

2. Mix one part of cattle urine with three parts of water

or

3. Mix one part of cow-dung (fresh) with four to eight parts of water, and remove all fibrous matter by straining the mixture through a piece of cloth or otherwise.

About half-a-pound of any of the above solutions will be enough for each pot per application, which may be done a day after the soil is stirred. The addition of liquid manure coupled with stirring of the soil frequently will enable the seedlings to shoot up into active growth very quickly. These treatments also help to maintain vigour throughout the life of the seedlings in pots.

The pots are kept in long shallow trenches with dry leaves spread below as well as in between the pots. The trenches are not more than about eight inches deep. In order to economise the cost of watering, ample water is let into these trenches once in eight days. The pots and the soil inside them absorb water freely to keep them supplied until the next watering turn. The dry leaves put below and around the pots help them to keep moist with this arrangement, the stock plants are seen to grow very satisfactorily. Thousands of stock plants can be thus raised with ease and economy. Hand watering of pot plants is laborious and costly. Pouring water from above splashes out some of the soil contained in the pot at each turn of watering. Plants have also to be watered daily as they do not get a copious supply on any day. If hand watering has to be resorted to for any reason, the pots require to be filled with fresh soil or compost every month if not more frequently, lest the roots get exposed and the soil in the pots gets removed gradually. The plants in such condition do not grow fast and vigorously, and make poor stock plants.

Watering

Stock seedlings have to be occasionally pruned to remove all side shoots, which may sprout from terminal and lateral buds in each flush. If left to grow, these sprouts rob the plant food of the main shoot, which consequently becomes weak and dwarf. The pots in which stocks are being raised have also to be lifted up and placed in different spots once in about two months or so. Otherwise, the long tap roots which have a tendency to go deep into the soil, emerge from the pots through the drainage holes at their

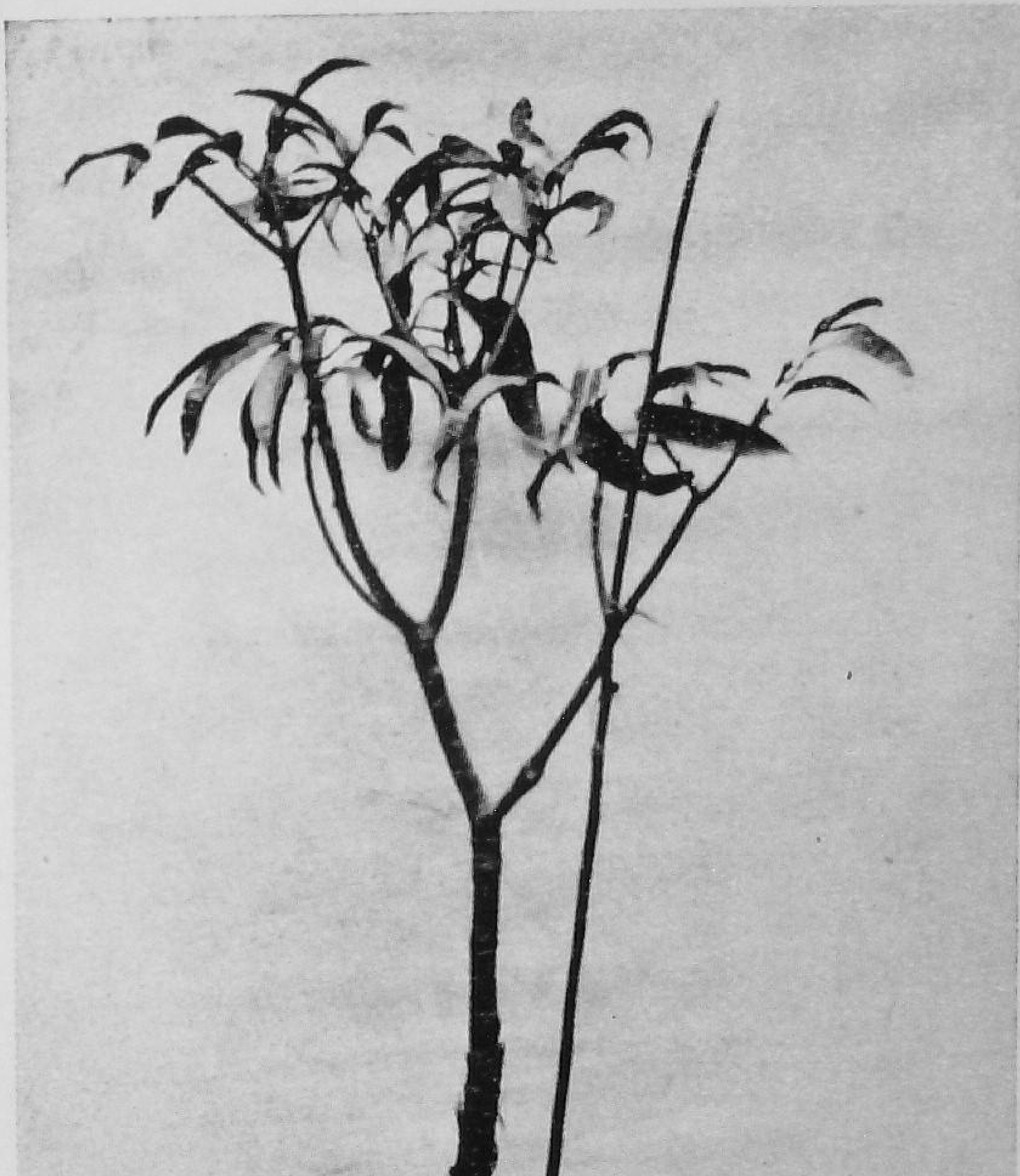
Further care

bottom and enter the other soil. If left undisturbed, they go deep into it and when it is time to lift the pots for grafting the stocks, it is difficult to take them out without tearing the roots roughly. In consequence, the stocks raised with so much care and trouble may be lost. It is, therefore, advisable to prevent the roots from entering the ground by lifting and replacing the pots occasionally. This operation can be easily done by having an alternate plot close by, where they can be shifted to.

With proper care and treatment, the stock plants get ready for grafting in twelve to fifteen months, when they attain a thickness of a lead pencil or about one centimetre in diameter at the height of six to eight inches from the soil. Commercial nurserymen use much older and thicker rootstocks for grafting. They use larger scions and produce big grafted plants for sale, which is profitable to them. It has, however, been shown in Bihar and Kodur (Madras) that grafting is very successful even on seedlings of three to twelve months of age. Grafts on very young rootstocks have to be kept for a long time in the nursery to enable them to attain a proper size to be planted out on the orchard site. Observations made at Kodur (Madras) on seedlings raised from different parent trees have indicated that the progeny of different parents differ markedly in vigour and in their rate of growth in nursery beds. This shows the possibility of cutting down appreciably the period from the seed to the grafting stage by selection of suitable seed parents especially in polyembryonic mangoes. The young mango seedling rootstocks require to be handled with care.

Grafting

Seedlings which are healthy and vigorous are taken to the scion tree for grafting by the enarch method. Enarching or grafting by simple approach consists of joining together a seedling rootstock and scion of equal thickness and age, by exposing their cambium layers and tying them together for a fairly long time, and then heading off the rootstock after detaching the graft from its parent tree. The actual operation commences with the selection of a scion shoot of equal age and thickness from a desirable parent for every seedling rootstock in pot. The scion shoot and the seedling stem are then tied together by giving them ties in two places so as to produce a proper bend near the place where grafting is intended to be performed. The seedling and



GRAFTING MANGO ON TWO STOCKS. *Facing page* 60.

the scion shoot are left in that position for about ten days. It helps the rootstock stem and the scion shoot to remain in position till grafting is done. After this period of about ten days, a thin slice is taken off both from the rootstock and the scion shoot with a sharp knife. The slice removed is roughly of about one third of the thickness of the stem or shoot. The exposure should necessarily be of equal breadth and length in the seedling stem and scion shoot, and should be slanting and gently tapering towards the ends so as to give a perfect fit when the two are joined together. The exposed portions of both the rootstock stem and the scion shoot are then brought together face to face and tied first with grafting tape or a strip of banana fibre and over it again with twine. Tying with banana fibre (*sopat* as it is locally called) is meant to prevent any constriction developing on the tender bark of the grafted plant as a result of tying with twine directly over the bark. Tying with twine has to be as close and as firm as possible in order that the cut surfaces may come into a very close contact with each other and leave no gap in between. Over the twine, a mixture of mud and cow dung in equal proportion is smeared to prevent the evaporation of moisture from the sides or ends of the joint. In Gandevi taluka (Baroda State), a mixture made of camphor (one part), *erio* (Aloe) (two parts) and fine earth (four parts) is applied possibly as a disinfectant. At times, a mixture of camphor and assafoetida is also smeared over the joint, while some growers and nurserymen are also said to have resorted to the use of grafting waxes made of paraffin, rosin, beeswax and tallow in different proportions. In South India, many use paraffined cloth instead of banana fibre for the first tying and Aloe or ficus fibre for the second tying. Nurserymen, however, are not generally particular about this. In Gujerat, long cuts (4.5 inches long) are made on both the stock and scion shoots, which are tied together with the cut edges facing each other by running thin coir string round the united portion. Neither *sopat* nor any wax nor mud is applied on the tied portion. The grafts made in this way develop defective joints with deep constrictions (15).

The rootstocks and the scion thus joined are left undisturbed for about a month and half. The seedling rootstock is watered daily, but care is taken not to pour water on the graft-joints lest they rot. The joint takes about 45 days to unite properly under

favourable weather conditions. The nurserymen allow 2-3 months before separating out the grafts. The scion shoot is detached from the parent tree gradually. To begin with, a cut is given to the scion shoot just below the graft-joint, about one-third deep. If after about ten days of this initial cut, the scion branch is not found withering, the cut is deepened to about two-thirds the thickness of the scion. If it is found withering, a longer period is allowed to pass. In about three months of grafting if the scion does not wilt, the union is finally taken as successful and the rootstock is headed off just above the graft-joint. Nurserymen often allow the rootstock also to grow until the graft is established in the field, in order that it may nurse the scion for a longer time. It has, however, been found at the Fruit Research Station, Gandevi that heading back of the rootstock before planting the graft in the open field helps the scion to gain vigour much faster than when the rootstock remains untopped. The cut ends of the rootstock and the scion are both properly trimmed and the grafts are left to establish themselves for about three months before they are planted out in the field or sold away. The banana fibre and string around the joint should be removed at the time of planting the grafts in the field. Grafting is done in March and the grafts are detached and sold in July by commercial nurserymen in the Gandevi taluka.

When the rootstock seedlings in pots are taken near the scion trees, a suitable arrangement has to be made to bring the scion branches and the rootstocks together. If the former are close to the ground there is no difficulty. Otherwise they are bent down to reach the ground by means of ropes and pegs fixed in the ground. If this measure is not feasible, a wooden platform has to be erected and the rootstock seedlings have to be placed on it close to the scion shoots for grafting purpose. In some regions, the potted rootstock seedling is tied to a strong limb of the scion parent close to the selected scion shoot. In some commercial nurseries as explained hereafter, the scion trees are specially trained to dwarf size to facilitate grafting close to the ground level. Recently a metal grafting-pot-stand has been devised at Kodur (Madras) to enable the enarching of scion shoots with seedling rootstocks without adopting any of the above-mentioned methods. The stand is clamped to a limb of the scion

parent after which, an adjustable arm of the stand having the potted seedling is brought to the desired position. This device enables the scion shoots from all parts of the tree to be selected and utilised for enarching, and renders it unnecessary to incur any recurring expenditure on scaffold or platforms, etc.

Grafting programme

In the Bombay State, where there is a regular and fairly punctual rainy season, and consequently a definite planting season when the rains break, the following programme can be followed with success in mango propagation

1. Sowing mango stones for raising rootstock seedlings —June, first year,
2. Grafting on rootstock seedlings—September, second year, *i.e.*, after fifteen months,
3. Detaching grafts from parent trees—November to December, second year,
4. Grafts ready for planting in the field—June, third year.

It would thus take two years for the graft to be ready for planting out in the field from the time the stones are sown for raising rootstocks. Very often, grafts are left unsold in pots for a long time and this results in stunted growth. Such grafts are distinguished by the greater thickness of the stock stem and the sickly appearance of the plant. These grafts are not desirable for planting out in the field, although the nurserymen may try to dispose them off at a cheap price.

Preparing scion trees

A very handy method of getting a sufficient number of scion shoots for grafting on rootstocks grown in pots, is to plant the scion trees considerably close to one another. When they grow for about five years, as many twigs are utilised for grafting as possible, and then the main branches are headed off at a height of about five feet from the ground. The stumps thus left give rise to "brooms" of new sprouts just below the cut ends. These sprouts can be grafted by enarching to rootstocks grown in pots, as soon as they are sufficiently mature. When all these new sprouts are grafted and the grafts are severed, a new crop of shoots becomes available and can be used in the following season for grafting. Instead of cutting away all the new branches of a

tree at one and the same time, they may be headed back in batches and allowed to grow alternately, so that a continuous supply of scion material is assured. A low platform is erected to carry the rootstock seedlings in pots near the scion branches for the purpose of grafting. A large number of scions can thus be taken from the same mother tree over and over again for several years. Such trees, of course, cannot be expected to yield any fruits.

In order to economise the raising of grafts, some of the commercial nurseries in South India raise the scion trees by a special and almost similar method. Trees are planted close to each other with a spacing of ten to twelve feet between every two trees. These are periodically topped and their limbs pruned severely so as to develop a very low headed bushy tree with a large number of small shoots spread all round the top. In such a case, the potted seedlings can be placed right on the ground and grafted to the low-lying scion shoots. The pots are sometimes buried in the ground so that water may be applied to them at long intervals along with the irrigation turns of the scion trees. These various measures enable the South Indian nurserymen to raise mango grafts at a very much cheaper cost than in the Bombay Presidency. The relatively longer time taken to separate the grafts from the scion trees also renders it possible for the nurserymen to sell the grafts to the public very soon (one or two months) after the separation.

A serious possible defect of the abovementioned procedure needs to be stressed. The scion trees trained by these methods do not bear any fruit and as such the grafts are raised from scion parents whose productive capacity remains unknown. Whether these artificial methods of continued suppression of the bearing tendencies of the scion parent, and grafting to scion shoots of rather succulent nature and of very much accelerated growth habit will affect the future bearing capacity and growth tendencies of the grafts as compared to the grafts raised from old and bearing scion trees, is a point which has been raised by many. Even if the productivity be a genetic factor, subject to the influence of environment and culture only to a limited extent, the fact that the above practice provides scope for the unscrupulous salesmen to sell their plants under wrong names is sufficient to discourage it.

In Ceylon the cleft or wedge methods of grafting and Forkert (modified) method of budding are commonly employed, and they have superseded the previously adopted method of grafting by approach.

Other methods of grafting

In parts of South India also, the method of grafting varies in some respects from that adopted in the Bombay Presidency. The majority of nurserymen in Salem and Chittoor districts raise the mango seedlings in nursery beds, and transfer them to the pots a couple of months prior to the time of grafting. In order to cater to the regional demand for very large sized plants, some nurserymen use seedlings of three or four years of age, but a large number of the nurserymen however, prefer one to two-year-old seedlings. The potted seedlings are taken near the scion parent and lopped at a height of nine to twenty-four inches from the level of the soil inside the pot. A slip of bark with some attached wood is removed from the seedling, by placing the knife 2 to 2½ inches below the lopped portion and then drawing it sharply upwards, thus causing gradual deepening cut inwards to the wood, so as to leave only a very thin slice of wood of ¼ to ⅛ inch thickness at the lopped end on the side opposite to that where the cut began. A corresponding cut is made on the scion shoot, which is then attached and tied securely to the rootstock, the exposed portion of the scion resting face to face to and resting on the exposed part of the rootstock. The advantage claimed for this method of grafting which is similar to whip grafting is that the rain water does not find a chance to enter inside the exposed wood, but merely flows down the wrapped parts of the graft union, whereas in the method (enarching) as practised in the Bombay Presidency and described above, a portion of the rain water may settle down in the crotch formed between the seedling rootstock and the scion shoot over the bandage parts and ultimately may find an entry to the exposed wood. The grafts are not separated from the scion parent for about three months after the actual operation. Because of the heavy rainfall and humid conditions prevailing during the monsoon weather, it is not found necessary to water the pots of the rootstock daily in the West Coast of the Madras Presidency except during very dry periods. Some nurserymen in these parts do not separate the grafts for even a year, in which case the rootstock seedlings are not watered after about three

months of the grafting operation, and, therefore, are allowed to draw their nourishment from the scion tree.

Recently, it has been shown at Kodur (Madras) that grafting direct to the root piece of the seedling is possible in mangoes. This method is similar to the method of bench grafting practised in Europe and America on apples, pears and grape vines except that, in this case only a piece of the root about two inches in length is exposed and this piece is grafted to the scion shoot. This method of grafting is believed to produce grafts of more uniformity in growth and bearing habit, and of greater resemblance to the parent trees than the enarched plants, in which case a portion of the stem-piece of the rootstock is retained. If these assumptions are proved in the case of mango, it will offer a suitable means of raising uniform planting material on miscellaneous monoembryonic rootstocks of varying constitution for field experiments. For commercial plantations, such grafts may not be popular because of the relatively greater difficulty in raising them and also of the difficulty in planting them without possible damage to the graft-union submerged underground and frequently wetted by irrigation water. The latter difficulty may perhaps be overcome by delaying the planting of grafts for some years till the graft-union is hardened by age and growth.

Side, crown, and cleft graftings have also been practised in mangoes in India with varying degrees of success. These various methods of grafting have been tried particularly for top-working old trees of inferior varieties.

Various combinations of vigorous or dwarfing scions and stocks were made and girth measurements of these studied at Sabour. Results are reported to show that (a) considerable difference existed in the size and vigour of unworked seedlings, (b) the dwarfing stock had reduced the vigour of scion and (c) when the scion was of a dwarf variety both the vigorous and dwarfing rootstocks produced dwarf trees. Dwarf scion on dwarf stock produced considerably smaller sized trees than the combination of dwarf scion on vigorous stock.

Budding of mango

Mango budding has also been attempted in several places with some promise of success. This method of propagation has attracted the attention of several workers all over the world on account of certain advantages over the methods of grafting. It is reported to be

successfully practised in Queensland, Florida, Philippines, Java, Ceylon and Egypt with some success. Shield budding is said to be more successful than bark grafting or patch budding in some places, while modified Forkert method has appealed most in other places. However, it is said that square patch budding known as 'Spring' budding has been reported to be successful in Florida. In Jamaica it has been suggested that seeds or very young seedlings should be put in their permanent position and budded nine to eighteen months later. The patch method of budding has been shown to be wasteful, and the ordinary T-bud method is recommended in Jamaica. Shield, Forkert and a modified Forkert method have been tried at Kodur (Madras) with a great deal of success, but the commercial possibilities remain still to be investigated. Budding of mango seems to have also been attempted at the Saharnpur Botanical Gardens, Uttar Pradesh (151) and in the Madhya Pradesh as early as the year 1899 with very little or no success. In the State of Bombay, Burns and Prayag (25) report to have obtained only eight per cent success in the total number of buds inserted. At Sabour the best budding season was found to be June and July, when 75% success was achieved in experiments conducted there. Buds from current year's growth which have reached a certain stage of maturity have given higher percentage of success than those from one year old wood. Later attempts, however, have shown that with a trained hand and proper selection of rootstocks and bud-wood, a larger percentage of success is possible. For success in the budding of mango, a great hindrance is caused by the following facts:—

(1) The bark of the mango seedling is not easily separable from the wood inside until the stem has sufficiently matured.

(2) The latex which exudes from the wound caused in the mango stem coagulates rapidly, and unless the bud is inserted immediately after it is cut, a layer of the coagulated latex intervenes between the surfaces of contact, and prevents union.

(3) The mango bud is very sensitive to the effects of the changing season.

In order to overcome these difficulties, the mango rootstock has to be allowed to mature sufficiently before budding is attempted

on it. A seedling rootstock of about three years of age with a diameter of an inch or more about eight inches from the base was found to make a good stock for budding upon at Poona. Vigorous plants in flush are to be selected for budding. Buds should also be taken from mature wood. The bud may be made to get plump, but not to open, on the selected tree by pruning the terminal growth of the shoot having the bud, at least a fortnight prior to use. Wester (190) suggests that leaf blades of the selected bud-wood must also be cut off at the same time and the leaf stalk may be allowed to dry and drop off in time. By doing so, the buds on the selected portion swell up, in which condition they are suitable for insertion and are in a very active state, congenial for quick union. The selection of the bud-wood and the necessary treatment to make the bud swell upon it are best done when the scion tree is or just about to be in a new flush. The effects of the latex mentioned above can be prevented, minimized or overcome by a dextrous hand sufficiently trained for the operation by long practice, and by inserting the bud soon after its removal from the scion parent.

The seasonal effects on the success of budding of mango are marked in this country, where the conditions of weather vary widely. In Poona, the percentage of success of budding was found experimentally on mango by inserting buds every fortnight of the year. It was revealed from these trials that budding in the months of August and September meets with the best results. During these months, the temperature of the atmosphere ranges between 60° F to 80° F. The heavy showers of the rainy season begin to subside having saturated the atmosphere with enough humidity, and the lighter showers at frequent intervals help to maintain the atmosphere cool and moist. Rains are, however, not desirable immediately after budding is done, because any water which enters the joints may cause the newly inserted bud to rot and thus kill it. In the case of plants in the ground, a short break of rains after the buds are inserted is therefore very essential. Paul and Gunaratnam (115) report that an improved method of budding mangoes in the nursery has been devised at the Farm School, Jaffna, Ceylon. Six months to one year old seedlings are budded at a height of about 10 inches from the ground. Bud is inserted in the flap between two parallel vertical cuts and secured with waxed tape. Budding of mango will

no doubt be a paying nursery practice. Besides, the operations being much less complicated than grafting, budded plants will be available for sale cheap. Recent investigations in different parts of India, particularly in Kodur (Madras) as also in Ceylon, point out to the possibility of the practice becoming an important feature of the mango nursery practice in this country. A large percentage of success in mango budding was obtained in Ceylon when done on some rootstocks than on others (109). During the rainy season (August-September) of 1935, 175 buds were inserted on new but mature shoots springing from old country seedling trees at the Modibag gardens in Poona. Of these, 35 buds took and sprouted by December, 1935. The trees were more than about twelve years of age. Their main branches were headed back to induce new sprouts to come up from below the beheaded region. Such sprouts were allowed to mature when budding was done. If this practice proves an economic success, as it certainly promises to be, top-working of old mango trees of wild and inferior varieties will also be an easy matter. Lal Singh and Naik (160) report that great success was achieved in budding mango seedlings *in situ* in the Punjab, while considerable work has been done in raising budded mango plants in pots and ground in Poona during recent years.

Preparatory tillage

Having selected the site for a mango plantation, the land is cleared of all wild growth. It is ploughed twice cross-wise, thoroughly harrowed and kept clean till the rains. As mango trees are also grown on hill sides or on the border lines of fields and other plantations, there is considerable difficulty in levelling such areas. At Ratnagiri the practice is to dig pits at required distances on undulated and sloping areas, without bringing them to level. In taking pits on slopes, the contour lines may be followed so as to restrict soil erosion and facilitate irrigation wherever possible. All tree growth near the pits is cleared off to provide an open area for the new mango plants to prosper.

Draining the soil

In ill-drained level lands, it may be necessary to provide artificial drainage either through surface or sub-soil drains. Shallow channels may be opened out across such patches or areas at suitable distances from each other, with a suitable number of catchment pits for preventing the washing of soil and finer soil fractions. Deeper

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trenches or lines of buried porus earthen pipes, or underground channels filled with brick stone, boulders, and brush-wood and providing enough inter-spaces, to permit the percolation and passage of water, may form the subsoil drains. Such covered underground drains may be laid out in a manner so as to allow a free flow of all the water passing through them to an open drain of the same or slightly greater depth, which in its turn may be made to empty its water into a stream or tank outside the orchard limits. The trenches in which pipes or other materials are buried may be filled up with surface soil at the upper 10 or 12 inches layer, in order to render the plot unbroken and convenient for tillage. By opening up of a number of open and covered subsoil drains, it has been possible at the Fruit Research Station, Kodur (Madras) to reclaim a plot of about three acres, which was previously considered unfit for any crop-growing, and make it suitable for the raising of a thriving mango and citrus plantation. It was also found at this place that, subsoil drains filled with boulders were as efficient as those with earthen pipes, and cheaper in cost.

"Surface drains prevent the sweeping away of the soil from the surface, but care must be taken that they themselves do not become carriers of soil. One or more silt pits in the course of the drains will arrest the flow of soil and silt. Open drains may be made parallel to the slope, while covered sub-soil drains should be connected to these in a slanting manner across the slope, but not at right angles to them. The depth of the covered subsoil drains will depend on the nature of the soil. It is important to see that open drains are left clean and free from weeds. Drains are particularly necessary in areas subjected to heavy rainfall and where the soil is stiff" (25).

Spacing of trees

Spacing of trees while planting depends upon the normal growth which they make when they are of the full bearing age. At no stage of the plantation should branches of neighbouring trees be allowed to intermingle, if possible. Mango trees assume large size and branching is generally well balanced on all sides. A distance of 35 to 40 feet is essential for mango trees under ordinary conditions. In fertile alluvial soil, particularly along the coastal region, even a distance of sixty feet between trees is not uncommon. Often plantations are seen so over-crowded as not to permit sun's rays

to reach the ground as a result of close planting. Actual cultural operations are hindered in closely planted groves. Proper orchard hygiene is also not maintained. Consequently bearing suffers. The trees give shelter to stem borers and other pests and diseases. Close planting therefore necessitates heavy pruning of the lower branches, if not the complete removal of intermediate trees at a later stage, in case the plantation is to be kept in good health. It is therefore most important to give a proper spacing at the very outset. In the coastal areas, 40 to 60 feet distance is considered suitable, while in the heavier soils of the Deccan and Karnatak a distance of thirty feet may be enough for planting mango grafts. In Gujerat, cultivators are adopting a distance of 50-60 feet between trees in mango plantations.

Pits

When the land is prepared and the spacing decided upon, pits of 3 feet by 3 feet by 3 feet are usually dug at the required distances during the hot weather. The soil of the upper half of the pits may be kept on one side and that of the lower half on the other while digging. The soil near the surface has been naturally subjected to weathering conditions and its ingredients are, therefore, in a more available form for the plant than the soil below. These two heaps are usually inverted while filling up the pits so that the surface soil is placed first into the pit and then the subsoil. It is generally advised to keep the pits open to the sun and wind for a couple of months at least before planting. This exposure is thought to help the interior of the pits to get properly "heated up" and weathered. If this is not possible, some kind of rubbish or brushwood is burnt in each pit. Burning in this way may improve the texture of the soil, and add ash (potash) to it. Before the pits are filled up, the two (soil and subsoil) heaps of soil are each thoroughly and separately mixed with about 25 lb. of well rotten cattle manure, one and a half pounds of bone meal* and two and a half pounds of wood ash. Wood ash may not be necessary if the pits are already burnt with brushwood, etc., as stated above.

*Bone meal of high quality can well be prepared by collecting stray bones of dead animals on the village side and storing them until required for use. These bones may be heaped with dry leaves and brushwood pieces in alternative layers, and partially burnt to make them brittle. When they are half burnt, they can be easily broken and powdered in an ordinary mortar

Filling up of pits should be done before the break of rains, so that the rain water does not accumulate and spoil the improved structure of the soil. The original bulk of the soil may be found to have increased by the addition of the manure. Hence if any soil remains in excess after the pits are filled, it may be kept in reserve near the pits for use if necessary after planting is done. In order to facilitate accurate spacing and planting in straight lines, it is advisable to drive a peg in the centre of the pit as a guiding mark.

It is the practice in other parts of India and also in some other countries, not to use any manure while filling pits. Manure is usually added a year after planting or 6 to 12 months prior to planting. This practice seems to be suitable where white ant trouble is severe. The placing of manure near the roots at the planting time is also considered at these places to be adverse to the new rootlets. Fresh manure gives out heat during the process of decomposition which may be injurious to the roots. It is, therefore, considered advisable to mix the manure in the soil some time in advance of the planting date.

Mango trees may be raised either *in situ* or by planting ready-made nursery grafts. The former practice is theoretically to be preferred to the latter, whenever, and wherever possible. *In situ* plantations require mango stones to be sown in the pits about two years ahead of grafting. When the seedlings thus raised, attain a height of about two or three feet, they can be grafted upon with scions of the desired varieties. Plantations of the second type are raised by purchasing grafts prepared in pots in nurseries and planting them out in the field direct. Planting of grafts thus saves considerable amount of time, labour and care. But *in situ* plants are believed to produce trees of a much superior stand and root system.

Planting

Pits are prepared and filled up in the same way as described above for both methods of planting. Soon after the break of rains or even a few days earlier, four or five well developed

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mill. It may be noted that by burning, the bones do not lose to any considerable extent their phosphoric acid for which they are meant. This practice, if followed, will be much cheaper than buying ready-made commercial bone meal. Besides, it will provide some employment in the villages, help village industries and thus promote rural uplift.

stones of country mangoes *ripened on the trees* are sown in the centre of the pits at a distance of a few inches from one another. Sowing may be done about two inches deep. The surface soil should be well pressed after sowing. Watering by hand is essential till the stones germinate and plants establish, unless sowing is done after the rains have set in, and rainfall is sufficient to keep the soil moist. On germination, the seedlings are allowed to grow for two or three months; and when they are about a foot high, only the strongest seedling is retained, and the rest clipped off close to the ground or carefully grubbed out from each pit.

In situ plantations of mangoes

The soil round the base of the plant in each pit may be stirred at least once a month. Some kind of liquid manure is given to the plants after each stirring. This treatment is said to invigorate the young seedlings, and if continued with adequate irrigation after the rains, the seedlings may become ready to receive the scion in a year when they attain a stem thickness of half an inch or so at the base. It is, however, considered unnecessary to apply any liquid manure, if the soil in the pits has been mixed with some sort of manure a few months before actual planting. As it is usually difficult to regularly bestow sufficient care on the plants scattered about in the field at long distances, it is preferable to allow the seedlings to grow undisturbed for another year. They can then be grafted or budded upon.

Grafting on such seedlings can be done either by the side-grafting method or by enarching. Except in the coastal tract where the atmospheric humidity is high for a long time, the side-grafting method is not generally very successful. In other tracts, ready-made nursery grafts are purchased and their scions are grafted to the rootstock plant raised *in situ* by the simple approach (enarch) method. For this purpose, it is desirable to buy grafts with more than one branch on the scion, so that a single graft in pot can be utilised to graft more than one rootstock in the field.

After the union is effected and the graft is separated from the scion parent plant in the pot, the rootstock plant in the ground is headed back to the graft-joint in due course of time. About three or four months after separation the wrappings around the graft joint are removed carefully. As the scion in this case has the advantage of growing on a free and extensive

root system of a vigorous seedling, the result is a far rapid growth superior to that observed in the case of plantations where ready-made grafts are planted.

Although, as discussed above, planting mango *in situ* is desirable, it is not much in vogue in actual practice. Ordinarily, growers decide on raising their mango plantations without much preliminary preparation or thought and follow the easiest and quickest method of doing it. The land is prepared, pits are taken and ready-made nursery grafts of the desired varieties are purchased at considerable cost and are planted. The owner has the satisfaction of possessing the varieties he wished for right from the very beginning of the plantations without a great deal of effort on his part in raising the grafts in nursery. This practice naturally creates a demand for nursery grafts and has consequently given rise to a regular and growing nursery trade.

Planting of nursery grafts

The method of planting nursery-made grafts in the fields direct is obviously simpler. While planting, the pots are broken or removed carefully so as not to break the ball of earth inside, lest the roots of the plants get damaged. Pieces of potsherds which usually get entangled in the coiled roots of the pot plants, are also carefully removed before planting. The grafts are then planted in the centre of the pits, burying them to as much depth as was originally in the pot, that is up to the collar. Planting deeper is not at all desirable, as any stem portion which enters the soil is liable to the attack of white-ants and other insects and may also get its bark rotted in the wet soil. It is definitely harmful to bury the graft joint of the plants in the soil as this is the most sensitive part of the stem. Not only that, the graft-joint should also be kept above the zone which usually becomes wet by irrigation water. It is a wrong impression that by burying the graft-joint, the risk of the graft being broken by strong wind is overcome. In order to protect newly planted grafts from high wind, which shakes the plant violently it is suggested that a strong bamboo or any other stick, which has previously been smeared with coal tar may be planted near each graft, and the graft tied to it rather loose in two or three places. It is also suggested that wherever possible, hedges or windbreaks may be raised around the plantation. At the time of planting or a few weeks later, the *sopat* and string which were used in tying the graft-joint should be removed.

The root system of the plants raised in pots is necessarily poorly developed, twisted and coiled in its search for food from the limited quantity of soil available to it. It is not infrequently cut and trimmed, if not torn, by nurserymen to prevent the tap root from entering the soil through the drainage hole. The plant consequently suffers and becomes stunted in growth, especially when allowed to remain in pots for too long a time. For this reason, it is always desirable to buy grafts which have remained in the pots for not more than about six months after the scion is detached from the parent tree, or that have been regularly repotted into larger sized pots at an interval of every six months up to about eighteen months after grafting.

Choice of grafts for planting

When nursery grafts are purchased for direct planting in the field, they should be properly selected. Such grafts, it may be repeated here, should not have remained in the pots for too long a time after the scion is detached from the parent tree, lest their growth is stunted and they look sickly. Grafts which have both the rootstocks and scion of uniform thickness and erect and straight growth should always be preferred to those, the component parts of which, do not bear any proportion to each other. The graft joint must be fairly long (about two to three inches) and should exhibit evidence of a perfect union. When the grafts have not been long in the containers after the scion has been detached from the parent tree, the graft-joint is generally covered with the grafting tape or string. While buying the grafts, one or two of them may be untied and the joints inspected carefully. When union is perfect, the rootstock and the scion will be seen clinging tightly together on all sides of the joint. New callus or healing tissue will also be seen developing on the border of the joint. If union is defective, the attachment of the scion and the rootstock as well as the callus formation will lack uniformity. Sometimes along the border as well as at the ends of the joints there may be a tendency for the separation of the rootstock from the scion, where normally there should be close attachment. After making oneself sure of proper union of the rootstock and scion, the joint may be again tied if necessary, in order to protect it further for some time until the graft establishes itself in the field. This step is unnecessary where the union is perfect and the graft has been

separated from the scion parent at least six months before the planting date. Grafts with a single, strong, mature, healthy and vigorous scion branch should always be preferred to those with weaker scions having many branches. The scion should never be thicker than or otherwise disproportionate to the rootstock in a graft. The whole plant should be such as if it were a well-knit combination of not dissimilar entities, forming a naturally growing plant of normal health and vigour.

In parts of the Ratnagiri district and the province of Goa, there prevails a practice of grafting a single large scion branch on two or three small tender seedlings raised in one container. The idea underlying this practice seems to be that a large mango graft can be easily obtained in a shorter time in this way than by allowing a single rootstock to attain the required size, and that two or three small seedlings can serve the purpose of one suitable and proper-sized rootstock for the scion. It is, however, found by experience that this is a wrong practice, in that it adversely affects the future tree, although it may give the nurserymen good profits for the time being. The scion in these cases becomes top heavy and the rootstock seedlings can rarely provide a strong and uniform support for it. This practice appears to be slowly dying out.

A large number of grafts of mango varieties is annually imported to the Bombay Presidency for sale from the State of Madras. These grafts are usually very large in size, being from three to four feet in height and are sold comparatively cheap. They are usually despatched immediately after they are separated from the scion parent tree. Growers are tempted to buy them, but the result is that many such grafts die soon after they are planted out in the field. Though these grafts are prepared on single rootstock seedlings, unlike in some nurseries at Ratnagiri, they are grown in small earthen pots for easy and economic transport. The pots are too small for the proper development of the roots. The soil contained in such pots is also too little to ensure an adequate supply of nourishment to the comparatively large plant. The plant, therefore, has a poorly developed root system. If, however, these plants are transferred to larger pots and kept in shade for two to three months before planting out, they are likely to attain their normal growth. Otherwise the grafts are generally unable to adapt themselves to the new

environments. They, therefore, succumb at an early stage to the great disappointment of the planter. Instances can be cited where hundreds of such grafts were purchased and planted in the field, and in spite of the very best care bestowed on them, only a few remained at the end of a year after planting.

Considerable difficulty is experienced in despatching mango grafts to distant places for planting. Apart from the high transportation charges, long-distance shipments of parcels involve a great deal of risk to plant life. The following method of despatching living plants by post has, therefore, been worked out to reduce loss and economise transportation expenses. Strong healthy grafts of one to two feet in height are selected for this purpose. They are kept in the open for full exposure to the sun and wind and are watered sparingly for about a fortnight. After they are "hardened" in this way all the leaves are clipped off, leaving only small leaf stalks. They are then taken out of the containers with the balls of earth intact and are made to stand in water for a few hours so that all the adhering earth can be carefully and gradually shaken off the roots. A suitable box is got prepared for packing in which a lining of oil paper followed by another of blotting paper, and over it a wet piece of gunny cloth are laid. Inside these a fairly thick layer of well moistened moss, cocoanut fibre or grain husk is spread and the plants are then placed over these in position horizontally. A layer of moss is spread over the grafts, which are then covered at the top with wet gunny cloth, blotting paper, and oil paper as on the bottom and sides, and the box is closed finally. It is then ready to be labelled and despatched to destination by post. Parcels of maximum weights of twenty pounds each can be sent by post in this country. About forty mango grafts of moderrate size can be packed in each parcel. On receipt of the parcel, the addressee who can be intimated of the despatch sufficiently in advance, should open it with the least possible delay. The plants should be taken out by him and submerged in water for about an hour. They may then be planted in suitable pots one by one. The soil used in these pots should be pure sand mixed with surface soil in equal quantities. The pots are then copiously watered and kept in a very cool and shady place, preferably in a shallow pit in the ground of a size sufficient to hold all the

Transport of grafts

pots standing together side by side. The sides of the pit are sprinkled with water before the plants are introduced in it. A wet canvas or gunny cloth is spread over the plants after keeping them in the pit. The pots are watered lightly as and when required. But sides of the pit as well as the gunny cloth canopy are kept moist by spraying or sprinkling water at frequent intervals during day time in order to provide a damp atmosphere to the plants. Gradually, and in the course of about ten to fifteen days the buds on the plants swell and sprout. The plants are then gradually exposed to the atmosphere, the gunny covering being removed at the beginning for short periods late in the evenings and early in the mornings only. When the plants have formed some leaves, they are taken out of the pit and kept in a shady place without any covering for some time, till they are considered fit to be planted out in the open. Both the processes of hardening at the place of origin and of reviving at destination are rather delicate operations that require some care and adjustment for success. With some experience, however, the operations will be found simple enough to be followed by laymen of average intelligence. The postal system of despatching fruit plants of an evergreen type as mango has yet to become popular in this country. There is, however, no doubt that it offers several advantages over the prevalent methods, particularly in regard to the despatch of the plants to foreign countries.

Irrigation

Mango seedlings raised and grafted *in situ*, as described before, have to be watered throughout the dry periods until they come to bearing, as in the case of nursery grafts planted in the field. After bearing commences, the trees are generally left to depend upon natural precipitation only. On the hill slopes of the Konkan tract, water is generally given to these trees by carrying it in earthen pots from the wells at the foot of the hills. This method of hand watering is very laborious and costly. Special earthen or stone structures are sometimes raised at the base of the trees on the hill slopes of Konkan in order to protect the trees from being dislodged by strong and frequent winds. Such mounds of earth also hold moisture for the trees during a large part of the dry period of the year. Water is generally given by hand on the top of these mounds, which are two to three feet high with a diameter of five to ten feet.

A KALTA OR MOUND OF EARTH AROUND THE TRUNK OF A MANGO TREE, SHOWING ROOTS. THIS IS A FEATURE OF MANGO CULTIVATION IN THE RATNAGIRI AREA.

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On the Deccan plateau to the east of the Western Ghats, mango plantations are generally raised on level ground. The most common practice here is to buy nursery grafts and plant them in pits. Watering follows, unless it rains soon after planting, and is continued by well or canal irrigation at regular intervals of eight to ten days. When the trees grow up and reach the bearing stage artificial irrigation is generally discontinued, as they develop by then an extensive and deep root system, capable of absorbing enough moisture from the soil to feed the trees. In the Indo-Gangetic plain and South India, mango grafts are rarely watered after three to four years of planting. On the hill slopes of the Malabar Coast, it is not uncommon to hand water the tree during hot and dry periods as in the Konkan tract of the Bombay State. Higgins (68) suggests that from fifty to seventy inches of irrigation per year should be given to mango trees, and the heaviest irrigation should be given from the time when the flower buds are about to open until several weeks after the fruiting is over, withholding large amount of water during two or three months preceding the flowering season.

Manuring

No definite standard of manuring mango grafts has yet been evolved either by common practice or by experimental investigation. Various doses are being tried of different mixtures including bones (whole or powdered), farm yard manure, slaughter house refuse, fish manure, etc.

The underlying principles seem to be to provide for the tree the three important ingredients, namely, nitrogen, phosphoric acid and potash, in one form or other, as they are commonly deficient in Bombay soils. Emphasis is, however, laid on the supply of bones to mango trees at all stages of growth. Bones are buried round the trees even at an advanced age in order to rejuvenate them. Burns and Prayag (25) state:—

"We recommend twenty pounds farm yard manure per tree for a year old tree, and then an increase of ten pounds per tree per annum, upto hundred pounds per tree. Similarly, bone meal at five pounds per tree for one-year-old, and an increase of one pound per annun upto fifteen pounds per tree. Ashes at ten pounds per tree and increased by two pounds per annum upto thirty pounds per tree."

These recommendations have not yet been adopted by growers. Whatever manure is applied, it shound be well mixed with the soil at the feeding zone of the trees and applied in the beginning of the monsoon, when rainfall is moderate. In heavy rainfall tracts, manure is best added after the severity of rains has abated, that is, in the month of September or so.

After the trees come to the bearing stage, it seems necessary to maintain their vigour by the application of suitable fertilizers once in every two or three years if not annually. Nitrogen and phosphoric acid appear to be the main requirements of the plants for this purpose and can be supplied in the form of bone meal and sulphate of ammonia or Niciphos II grade. It is desirable to use farm yard manure in combination with these artificial fertilizers. The following doses of manures for trees about twelve and twenty-five years of age are recommended by Wagle (183):

		Trees of 12 years of age.	Trees of 25years of age.
I.	Bone meal,	15 lb.	20 lb.
	Sulphate of ammonia,	5 lb.	6 lb.
	Farm yard manure.	50 lb.	75 lb.
or			
II.	Niciphos II grade,	9 lb.	12 lb.
	Farm yard manure,	50 lb.	75 lb.

"The doses for smaller or bigger trees may be changed proportionately according to their age."

The application of common salt as manure to mango trees is a practice with some growers in Konkan (57). Woodrow (193) has recorded that the mango growers near Bombay apply ten pounds of common salt to each tree in the month of September. The practice is stated to be helpful or at least not harmful in a moist climate with a heavy annual rainfall. In the drier tracts of the Bombay State this practice does not exist, nor is it in vogue in the humid zones of South India. Paranjapye (107) reports that in certain cases where the Konkan practice of applying common salt was followed in the Deccan, the trees actually suffered from its deleterious effects. Burns and Prayag (25) record the result of an experiment they carried out at Poona, wherein they state that the application of common salt seems

to have no effect on the time of flowering. They dissent from the opinion of Gonehalli (57) who explains that the use of salt is "to keep off white ants, to retain soil moisture and to arrest vegetative growth". Some land owners at Ratnagiri observe the following rotation in manuring their coconut and mango trees :

1st year	Cattle manure
2nd year	Fish manure
3rd year	(Salt 10 pounds per tree)

Some manurial experiments on mangoes carried out at the Fruit Research Station, Sabour, Bihar, reveal that nitrogen in the form of ammonium sulphate is the most effective in increasing the flowering of mango trees, and that the best time of application of nitrogenous manure in any form is the month of June.

In Florida, two applications of a pound each of a fertilizer containing about 6 per cent nitrogen, 6 per cent phosphoric acid and 4 per cent potash during the first year after planting are recommended (144). The first application is made in spring and the second in summer. The amount is doubled in the second year and gradually increased until the trees reach full bearing age. Mature bearing trees are given annually from twenty to forty pounds of this fertilizer divided into three or four applications. No fertilizer is, however, applied during the blooming and early fruit-setting period. Macmillan (84) recommends a mixture containing one part blood meal, one part superphosphate, half part bone meal, and one part sulphate of potash to be applied at the rate of six ounces per tree which is one year old, twelve ounces each to those which are two years old, and four pound each to trees six years old. Experiments carried out for over six years at Sabour show that the application of phosphorous and potash singly or in combination had little effect on growth, but nitrogen in combination with either or both of these elements had better effect on growth than nitrogen alone. Flowering further was observed to be directly proportional to growth (143).

The value of such trials may not be of widespread application because of limiting factors such as diversity of environments and multiplicity of varieties. The Sabour trials with trees of a particular age and vigour cannot also hold good

with other trees of different age and condition of growth. Above all, the cost of manures and fertilisers may render their application not always feasible in mango groves.

The young mango trees are planted in most parts of the Bombay Presidency with a spacing of over thirty feet, which means that there is considerable open space left between them. In order to utilize this space and to earn some income to pay for labour, manure, etc., some kinds of seasonal vegetables or short lived fruit trees may be grown between mango trees. The usual practice is to grow *bhendi* (*Hibiscus esculentus*), *Guvar* (*Cyamopsis psoralioides*), *Kulthi* (*Dolichos biflorus*), groundnut (*Arachis hypogaea*), peas, etc., during the monsoon every year until the mango trees cover the interspace fairly well by their own spread. Perennials which shade the young trees are not desirable as inter-crops. In the Modibag Gardens, in Poona and at the Sabour Fruit Research Station, Bihar, papaya trees have been grown as an inter-crop between mango trees with no harmful results. A very intensive system of cropping was also practised at Poona wherein seasonal vagetables such as Knolkohl, cabbage, radish, etc., or fruit plants such as cape gooseberry were grown together with papayas in mango plantations. When the mango trees grew up, a dwarf variety of banana was planted between the mango rows. In Gujerat, near about Amalsad crops of pineapple and black pepper (*Piper Longum*) are grown in mango groves. In the Baroda State, inter-crops of sugar cane, *suran* (*Amorphophalus campanulatus*), ginger (*Zingiber officinale*), turnip and later on pepper, and pineapples are usually grown.

Inter-crops

In the warmer regions of the Presidency of Bombay where the atmospheric temperature exceeds 110°F for several days during the summer, small mango grafts are sometimes planted at the usual distance in banana plantations. Banana plants shade and protect the young mango plants until they are established; after the mango trees are two years old, the banana plantation is removed. This practice is fairly widespread in Bijapur and Khandesh districts. Collins (32) has also recommended a similar practice for Porto Rico. In the Punjab and Gujerat, bananas are planted by the side of newly planted mango grafts and sometimes of mango seedlings also as a nurse crop. In the Surat district, sugarcane is taken as an inter-crop in well drained

YOUNG TREES ENTIRELY HIDDEN IN THE INTER-CROP OF JOWAR (ANDROPOGDU SORGHUM), AN UNDESIRABLE PRACTICE.

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soils. Growing of mango together with crops of entirely varying requirements for moisture, culture, etc., as sugarcane and banana is a practice difficult to be justified as sound; but with an adaptable and hardy fruit like the mango no marked ill-effects have been observed due to such inter-cropping methods. The question of inter-cropping does not, however, arise when mango grafts are planted in a line on the border of fields or other plantations, as is very often done.

Inter-tillage

Mango trees, when young, require that their basins should be frequently stirred after irrigation. When they are established, however, the inter-space is ploughed once or twice in the year and left exposed to absorb rain water, as and when it may be received. In actual practice, manure is rarely applied regularly to grown up trees, and whatever dry leaves drop off annually beneath them, are ploughed into the soil. Even this is not possible on rough hill slopes as in the coastal tract (Konkan), where adult mango trees are simply left to themselves except for gathering of the fruit crop. Proper tillage is only given on level ground where inter-cropping is also possible. Clean cultivation all through the year is never practised in mango groves nor is it advisable, as it results in a too rapid depletion of the soil humus. Clean cultivation during the dry seasons combined with the growing of cover crops during the rainy seasons is recommended for both citrus and mango groves in Florida (144). Cover crops, however, can be grown with difficulty in bearing mango plantations, and at any rate are not profitable except when they are grown for green manuring purposes.

Pruning

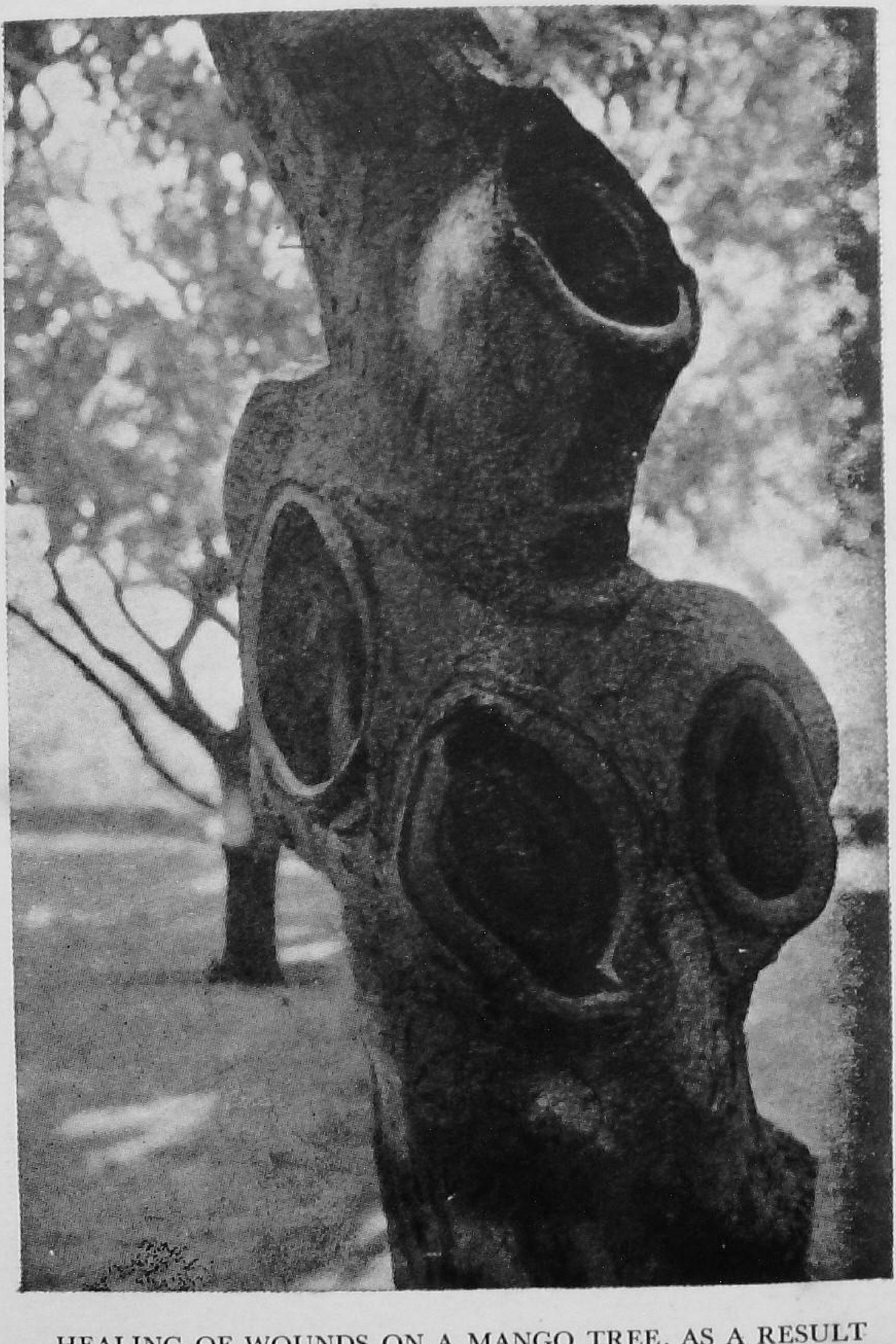
Mango trees are not ordinarily pruned. If left to themselves, most of the seedling trees of mango are seen to develop a very graceful dome shape with a clean straight trunk. Grafted trees of some varieties, however, branch low and spread out without any regular shape. Often grafted trees send out large branches close to the ground and it is difficult to do any cultivation below them. Such branches may well be utilised to take scions for grafting purposes. Later, the thicker branches also may be pruned close to the main trunk so as to clear up the base of the trees for cultivation. Several varieties in the Uttar Pradesh, Bihar and the Madras States are erect growers with a fairly high

head and, therefore, the above measures are unnecessary in their case. Burns and Prayag (25) state—"We have studied several hundreds of flushes from their inception to the time they flower, and are convinced that there is no possibility of pruning for flowers, as any kind of pruning may lop off a potential flower bearing branch". Mango stems, however, have to be pruned to varying extents when they are severely affected by loranthus and stem borers, as described elsewhere.

Thick branches of seedling mango trees have also to be pruned back heavily in order to stimulate the growth of a large number of vegetative shoots for grafting upon. When these shoots are mature, they are grafted to scions of superior table varieties. Budding is also fairly successful on such shoots if it is done in the proper season. This practice is known as top-working and is described elsewhere. It is mainly resorted to when large seedling mango trees have to be converted into good types for economic reasons.

Transplanting of mango trees

Occasionally, large mango trees are used to fill up gaps in regular plantations. It is difficult to shift large trees to long distances, and hence transplanting has to be done within close limits. Trees selected for this purpose have to be severely pruned of all the leaves and smaller branches before they are lifted. The remaining portion is then wrapped with straw and moistened to prevent it from drying up. A cirular trench is dug round the trunk of the tree about two or three feet away according to the size of the tree. This trench is deepened and cut inwards. All roots coming in the way are cut off. The conical ball of earth round the roots of the tree thus prepared is then carefully wrapped in gunny cloth and coir to prevent it from breaking. The tap root of the tree is then cut, and the base of the earthen ball also included in the gunny cloth wrapped and tied well. The whole tree with the ball of earth is then lifted carefully by means of a crane or levers and shifted to the place reserved for its planting where a suitable pit is kept ready to receive it. Planting is done in the new pit, and all soil filled into it is well pressed and the trunk of the tree is supported from all sides with bamboo or other kinds of support, to keep it steady against wind or other physical disturbances. Copious water is given to the tree and the covered stem is also sprayed



HEALING OF WOUNDS ON A MANGO TREE, AS A RESULT OF PRUNING THE BRANCHES CLEAN TO THE BASE WITHOUT LEAVING ANY STUBS.

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with water to keep the straw moist. This will hasten the buds to sprout. Excessive spraying with water may cause the bark to rot and the tree may die in course of time. When the buds sprout and new foliage is formed in about two months from transplanting, the straw covering is removed and the tree is allowed to grow freely in its natural condition. Transplanting large mango trees is best done when the atmosphere is cloudy or when it is drizzling during the monsoon. Trees about five years old or under may be transplanted very easily without using straw and taking other precautions described above. Seedling mango trees growing in the jungle can be shifted to cultivated areas according to the method described above and used as rootstocks for grafting upon with superior varieties, so as to secure large trees in a relatively short time. But this is unlikely to be economic in most places.

Rejuvenation of old mango trees

It is a well-known fact that mango trees live for a hundred years or more and grow to huge dimensions. Popenoe (124) referring to the records of Charles Maries states that mango trees were found in North India in thrifty condition even 300 years after planting. Old trees have a tendency to develop hollows in their trunks and main branches starting from the crotch or the point of bifurcation. Rain water is deposited here and this causes the bark and the wood inside it to rot; and as the process continues year after year, large cavities are formed. Similarly, when a branch is broken by wind or by other means, the untrimmed stub left behind usually rots and dies. Gradually, a cavity may be formed at this point too, which may later run deep into the main branch. A historic *Borsha* mango tree of huge dimensions, reputed to be over three hundred years old at Kalamsar in the East Khandesh district, had one of its three main branches broken by wind. In course of time, the main trunk developed a hollow in which three to five persons could enter at a time. The whole tree was in danger, but it has now been saved by the following method: All the dead wood was cut and scraped off until the living tissue was reached. The exposed portion was smeared with coal tar as a disinfectant, and the cavity was filled with lime mortar together with several well baked bricks to make up the bulk. When the cavity was properly filled without leaving any interspace between the bricks, the opening

was neatly plastered with cement. This operation gave strength to the remaining portion of the trunk as callus formed all round the cement facing. This process has been adopted in filling up several tree cavities with great success at the Ganeshkhind Fruit Experiment Station, Kirkee. Neat trimming of all stumps of broken or cut branches and applying tar immediately afterwards on the cut surface in order to enable the trees to form healing tissue (callus), are, therefore, desirable measures recommended to prevent the formation of cavities. Hot tar is dangerous and should not be used over living tree parts.

Old trees and sometimes even young groves of mangoes are seen in many parts of India in a neglected condition with scraggy and unhealthy branches full of loranthus and stem borers. Such groves cannot be expected to be remunerative, even if the trees are of the superior table varieties. Rejuvenation of these trees can be accomplished by properly ploughing and cultivating the land, removing all borers and loranthus by the methods explained elsewhere and by applying the following dose of manure per tree of 15 to 20 years of age at about the commencement of the rains:—

20 pounds of bone meal,
200 pounds of well rotten farm yard manure, and
5 pounds of oil cake of any kind.

The above dose may vary according to the age and size of the trees.

Top-working by various methods is reported to have given uniformly successful results at Sabour. Top-working old mango trees by cleft-grafting, budding or bark grafting is also recommended by some persons. It has to be remembered, however, that top-working an old tree in a declining state will serve no purpose whatever, unless steps are taken to invigorate the tree by better feeding and grove culture. Old mango trees in weak health can also be invigorated by infusing fresh sap of younger seedlings into them. The method adopted to achieve this object is as follows: Several young mango seedlings or stones are planted close to the trunk of the tree. When the seedlings have grown for two or three years, they are headed off at a height of two to three feet from the ground level. The cut ends are then shaped to a wedge form to a length of two inches in the fashion of the ends of a fountain pen facing the tree, and inserted

DOUBLE GRAFTING OF MANGO.

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into the bark of the latter and tied up. The insertion of the seedling stem pieces should be done in a manner that the exposed sides of the seedling stem are fairly embedded between the inner wood and the bark of the tree. , In course of time, the seedlings get grafted to the old trees, and serve as its feeder trunks.

In the Baroda State and the Gujerat districts of the Bombay Presidency, a common practice of strengthening nursery made grafts planted directly in the field is to plant one or more seedlings near the graft, and when both the seedlings and the graft have grown for sometime, the seedlings are grafted to the branches of the graft by the enarch method. The seedlings are headed off when the union is complete. The branches of the original graft are thus able to draw plant food through the new seedling root-stocks, and consequently grow with increased vigour. The debility of the original graft, if caused by its twisted and poor root system, is thus remedied.

Flowering and pollination

Marloth (88) observes that the structure of mango flower provides for pollination by insects. Self-pollination has been observed to some degree in a few varieties. Research has so far not been able to explain the failure of certain varieties to flower normally and regularly in S. Africa. Under normal conditions, inflorescences in the mango develop from terminal buds and if the terminal buds are removed during the flowering period, inflorescences are produced by axillary buds which would normally remain dormant. Experiments on girdled and decapitated branches indicate that, when leaves are present above the girdle, floral induction takes place in the axillary buds in a period between one and four days after the treatment (136). According to the observations made at Sabour (Bihar), fruit bud differentiation was first detected at the end of September and progressively increased upto the middle of November. This does not explain how some of the new growths emerging towards the close of the calendar year also produce blossoms within a couple of months of their emergence.

Periodicity of bearing in mango trees

Mango trees are notorious for not bearing a good crop annually. Some trees in the same plantation may bear heavily in one year, while others may not. Even on the same tree, a few branches only may bear fruits in a year and the remaining branches

may bear in the next year or a few years later. The cycle of periodicity of bearing is alleged to be completed in three years in the Bombay Presidency, except in the case of the *Totapuri* variety where it is said to be completed in two years. This, however, does not hold true in other parts of India. Local conditions of soil, climate, cultivation and other factors may wield varying influence in different mango regions. This problem has yet to be studied experimentally before any definite idea can be given.

According to some authors biennial bearing is not the inherent feature of many varieties of mangoes and that an optimum crop can be secured every year, provided the tree has made normal vegetative growth under natural conditions in the preceding season. The work carried on at Lyallpur and Kodur lend force to the belief that the effects of so called alternate or irregular bearing in mangoes can be minimized by a suitable cultural operations programme. It was noticed at Sabour that in the case of old trees with "alternate bearing" habit, treated trees gave more flowering than control in the following year, but in the case of young trees just coming into bearing, no beneficial effect was observed. It was also observed that flowering could be induced in the "off" years by ringing in the "on" years. Half inch ringing of branches in the "on" year in August followed immediately by manuring with farm yard manure plus ammonium sulphate produced better results than "ringing alone" and "manuring alone". From an experiment in progress at Bihar (Sabour) the results indicate that ammonium sulphate plus farm yard manure applied after harvest (June) gave significant increase in flowering. The treatment given annually during five consecutive years increased the level of flowering both in the "on" and "off" years, but showed little effect on the so called biennial rhythm. Applications are now being made in the "on" years only (143)

Hartless (64) has shown that at Saharanpur, mango trees bore during the period from 1886 to 1912, an average crop in three years, heavy crops in nine years, and poor crops in fifteen years. Insect pests, drought in the spring, frost and cold, untimely rains and excessive growth favoured by climate are the causes that were responsible for crop failures. It is also revealed in the records collected by Hartless that on two

occasions, two abundant years occurred in succession, and on both the occasions three bad years had preceded the phenomenon. These facts show that in some parts of India, alternate bearing or periodicity of bearing, strictly speaking, does not either exist, or if it does exist, it is subject to the modifying influence of a number of external agencies like pests, diseases, and weather conditions.

It has also been shown in Bihar (16) that a heavy year in mango crop is obtained in that Province once in six years. Experience in other parts of India also seems to reveal that the periodicity of bearing is not a regular phenomenon in all mango varieties, and under all conditions. There are, no doubt, "off" and "on" years occurring at irregular intervals, but to what extent these are caused by the various factors mentioned above is a point on which light has yet to be thrown. Wagle (183) records his observations in the Bombay Presidency in this regard as follows:

"Mango trees usually bear in alternate years, but as a result of manuring trees, particularly, of ten to twelve years of age, they began to bear in successive years." He gives a three-year record of the yield of several trees to substantiate this statement, and adds that the vigour of the trees is very well maintained by manuring in spite of their annual bearing. He attributes the improvement in bearing to production of more complete flowers developing into mature fruits later on as a result of manuring. He experimented with sulphate of ammonia (2 pounds), superphosphate (2 pounds), farm yard manure (2 baskets of 40 pounds), and Niciphos II grade.

Popenoe (124) has also drawn the conclusion that the failure of crop in mango is due to physiological causes "connected with nutritional conditions as influenced by changes in soil moisture and food supply, principally the former." After a heavy bearing probably the tree becomes weak and cannot produce blossom during the succeeding year until it can recoup its lost vigour. As shown above, a proper supply of the chief plant food ingredients in the form of manures, coupled with adequate irrigation may improve the situation and cause the trees to bear more frequently if not annually. Hartless (64) has recorded that at Saharanpur, the finest year for mango was the one that followed an early closing of the monsoon. The

relation between the growth of the previous season or the cessation of the growth activities in that season and the productivity in the succeeding season is indicated from the above observation.

Smudging

The practice of smudging is reported from the Philippines. Dry leaves, straw, brushwood or weeds are used as fuel to produce a thick pall of smoke. Sometimes, small quantities of sulphur are put in the fire thus caused. The tree is smoked heavily and continuously day and night for a week. Thereafter, light fires are made morning and evening for about a month or until the trees come to bloom. If the trees fail to set crop, a second smoking is given. Borja and Butista (18) obtained best yields by smudging the trees in December and January. November smudging was not successful. Trees not producing flowers within about fourteen days of continuous smudging will not, it is stated, do so at all in that season. Gonazalez (55) reports from the Philippines that mango trees can be made to flower at any time of the year by smudging. It was commonly believed that it is the smoke that induces the blooming, but work done in the Philippines indicates that it was the heat and not the smoke that induced flowering, the number of flowers produced being proportional to the rise in the temperature subject to the limits of safety. The best period for smudging was determined to be between October and December, when the leaves would be well developed and the terminal buds dormant but well formed. The smoke produced at the smudging period drives away the injurious insects which, however, return at a later stage. Smudging was tried at Kodur, but the results were conflicting, from which it is inferred that this treatment cannot always be depended upon to stimulate production.

Crop failure due to diseases and pests

One of the chief reasons of the poor bearing of the mango tree in some years is perhaps the shedding of flowers caused by the hoppers and mildew, so often noticed on mango trees during the blossoming time and specially encouraged by cloudy weather. The hoppers cause physical damage to the flowers when they jump about in large numbers causing them to drop. "The frequent occurrence of the mildew on inflorescences when shedding is going on has been noticed, though the con-

nection of this fungus with shedding itself has not been hitherto demonstrated" (179). This fungus is supposed to develop on the sugary secretion deposited on the leaves and flowers by jassid hoppers, and further found to be responsible partially or wholly for damaging the crop.

Working on the effect of the hoppers and the mildew found on mango inflorescences, Wagle (182) states "It may therefore, be taken as proved that the insect can be the cause of the complete loss of the mango crop." He further states "...... even excluding other influences causing loss of fruits, the mildew was capable of completely destroying the crop as occurred in the first and third flushes of 1925-27, or in the other cases of reducing by one-third (second flush of 1926-27), or by more than one half (1925-26) in two separate cases." Dealing with the remedial measures tried and found successful in checking these hoppers and mildew, Wagle (182) reports that dusting with sulphur is effective both against the hopper as well as the mildew.

Sex distribution

It has been recorded (23, 182) that the mango inflorescence bears flowers of three types—the complete, the staminate and the pistillate. Pure pistillate flowers have, however, been found to be practically absent in sixteen mango varieties studied at Kodur (Madras). It is only a very small percentage of the complete flowers that set and develop into mature fruits. The proportion of complete flowers in the most important commercial variety of mangoes in the Konkan (coastal) tract of the State of Bombay, namely, Alphonso, is worked out to be highly variable, from nil to fifty-five per cent. produced even in the same flush. The average proportion of these complete flowers was found to be not more than about five per cent. of the total number of flowers. Of the small percentage of complete flowers, nearly half are shed before fertilisation, and almost as much soon after fertilisation. Ultimately, the percentage of flowers which form mature fruits is less than one.

Similar study was undertaken by Popenoe (123) at Florida, Maheshwari (86) in Northern India and also at the Fruit Research Station, Kodur (Madras). At the last centre, a study of 93,305 flowers of 16 different varieties during 1939 season has shown that, the percentage of perfect flowers was the largest in *Neelum* being 16·41 and the least in *Allampur*

Beneshan, being 3·47. *Goa*, *Amlet* and *Khader* come very near to the *Neelum* standard, while *Baneshan*, *Mulgoa* and *Erra Mulgoa* are more or less on a par with *Allampur Baneshan* in this respect. These results considered together with the known performance of varieties seem to indicate that a high percentage of perfect flowers is closely associated with high productivity. Maheshwari has pointed out that the number of flowers in mango panicle ranges from 1,500 to 4,000. Despite such a large number of flowers, it is rare to come across a panicle bearing more than a maximum of about 10 fruits at the mature stage. A very large number of commercial mango varieties, however, rarely produces more than one ripe fruit per panicle, while a bulk of the inflorescence normally withers away without maturing even a single fruit. Increased set of fruit and better capacity to hold fruits to maturity are, therefore, the two most important objectives that merit the attention of mango investigators. A solution to these problems will considerably assist the evolving of a solution of the allied problem of periodicity of bearing in mangoes, as in several years it has been observed that a heavy crop of blossoms is followed by a very poor yield of fruits, even though the hopper incidence is not severe and heavy rains are absent during the season.

Growth in relation to cropping

The relation between the fruit bud formation and vegetative growth in mangoes was studied in the Philippines at Manilla (52). The materials used for this study were seedling and vegetatively grown *Carabao* mango trees, this variety being the best known there. Both heavy bearing and light bearing trees under similar climatic conditions were studied. Since flowering of the mango trees depends upon the previous year's growth, observations were confined to this portion of the branches only. From the results of biometrical observations, it was found that,

1. "There is a relation between the length and the diameter of the twigs and fruiting. In the case of non-bearing robust trees, there was an abundance of vegetative growth—length and diameter, compared with the bearing trees."
2. "There is a relation between the leaf area and the number of leaves, and fruiting. As the number of

leaves increases each with a less leaf area, the less fruitful the tree becomes, as in the case of the non-bearing robust trees."

3. "In the case of bearing trees, the average length and diameter were greater than those of the non-bearing, but less leaf area."

That a definite relation exists between flower bearing capacity of the shoots and their previous growth characters, such as the average length and the number of the new growths produced, was also indicated in a study carried out in the Punjab. It was also known that the average extension growth as well as the number of the new growths are markedly greater in shoots that did not flower in the previous year. Biometrical studies were pursued on these lines at Sabour (Bihar) and Kodur (Madras) under the aegis of the Indian Council of Agricultural Research, and these too have corroborated the preceding inferences generally.

Observations made at the Modibag, Poona, show that the mango shoots should be sufficiently mature for bearing flowers and that they take about nine months from the time of sprouting to attain the required maturity. The mango trees invariably blossom in the cold season, beginning from the month of December. In order, therefore, that the shoots may be sufficiently mature by December, they must have sprouted in the preceding March at the latest. It follows that, no shoots which are put forth in the flushes of the preceding June-July or September-October season, can be reasonably expected to blossom in the following December. An attempt was therefore made to arrest all new growth which may sprout out during these two flushing seasons by suppressing growth from buds. The result was that a large number of the older pruned shoots produced blossom and bore fruits. These observations are not yet conclusive, and have to be further confirmed by large scale experiments. Observations at Kodur have, however, revealed that in such varieties as *Neelum* and *Suvarnarekha* even the shoots arising in October can produce blossom in the following February.

Vegetative growth of trees may also be checked to some extent by artificial methods like ringing, girdling and pruning of the

Growth regulation

roots. Girdling was tried in the Punjab and it was found that it produced a large number of new shoots with a good extension growth, and reduced the extension growth of the first flush shoots. The practice, however, was not found to be feasible for increasing flower production due to the difficulty in rapid healing of wounds. Rough methods of girdling mango trees by making wounds on the bark of the trees with an axe are commonly practised in many parts of India, with the object of making shy bearers productive. No experimental evidence is available for justifying this practice, but from a survey of a few orchards where this system is regularly practised, it appears that the claims made for this method are exaggerated. In any case, the method cannot be relied upon to give good results invariably. The efficacy of root pruning is also doubtful on the mango tree, which does not seem to relish such treatment.

Double-grafting is another process that may perhaps be advocated to force the mango trees bear annually. It consists of grafting a scion of prolific variety on rootstock, and then again grafting the ultimate scion on the graft. Such a process is believed to arrest excessive vegetative growth of the tree making it dwarf, and hastening and regulating bearing. No experimental data on the aspect of double-grafting in regard to mango are available to support this view at present. Double worked plants of four varieties at Kodur have generally produced dwarf trees so far.

Hybridization

As in most other Indian fruits, hybridization work has not been attempted in India towards the improvement of mangoes except at Kodur and Sabour on a small scale. This is to be regretted, especially as there is no dearth of valuable germ plasm amidst the wealth of variations among the cultivated and wild mango varieties and types in this country. Apart from the usually long time factor required for the successful conduct of this kind of work, there is also the handicap before the mango breeder, of a low percentage of fruit set. Out of about 8,000 controlled crosses made with various varieties in Kodur (Madras), hardly 100 developed and reached the final maturity stage. Further work is called for to increase the set. There is no doubt that such lines of work are urgently needed to be undertaken

on a nationwide basis in India, where there are excellent opportunities for effecting a rich variety of recombined characters. At Kodur, three F[1] hybrids have already been selected as of sufficient merit deserving multiplication, and also some chance seedlings have been adjudged as noteworthy (143).

Top-working means the renovation of the whole of the top of a tree by inserting scions on the existing branches, so that these scions may grow in place of the old branches of the tree.

Top-working of mango trees

This method is practised on various fruit trees in several foreign countries including Florida and the Philippines (22,109,125). Top-working by adoption of crown grafting methods necessitates the cutting off of the tree top wholly at one time, and the scions when inserted on the crown are left exposed to the hard conditions of the field. Where the branches are cut one by one and the new sprouts that spring up just below the cut ends, are top-worked to the scions of desirable varieties, by placing the potted grafts over an improvised platform or held in position by some other suitable means, a larger part of the tree is saved and the subsequent growth of scions is afforded greater facilities. When the union takes place, the scions are separated out from the potted graft and allowed to grow on the top of the worked tree. It is necessary to graft several scions in order to top-work a single tree by this method. The purchase and preparation of a large number of grafts, and their care when placed at a considerable height from the ground, until the scions have united with the stock branches, all constitute tedious and expensive items. When the scions establish themselves, they however, need little care. Top-working is a useful method of converting large inferior seedling mango trees into superior types, of hastening their bearing age, and of shortening the period of testing seedling progeny secured by breeding projects, etc. As the rootstock tree is usually well established with an extensive root system, the scions worked on them, grow quickly into vigorous trees and bear fruit early. In Goa and other parts of the coastal tract, side-grafting is practised on fairly old seedling trees raised *in situ*. This tract receives very heavy rainfall during about four months in the year. The annual precipitation entrated during the months from June to September ranges)0 to 150 inches. Consequently the atmospheric humidity

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is very high. The temperature ranges between 70°F and 100°F. These factors are all favourable for vegetative growth. Side grafting under such conditions meets with fair success. Crown and whip grafting methods may perhaps also succeed in this tract, but these are rarely practised. Side grafting has a decided advantage over these two methods, in that the rootstock remains quite intact in case the scion fails to "take" and easily lends itself to regrafting, whereas in crown and whip graftings the rootstock has necessarily to be headed off before the scions are inserted. The best time for grafting mango in the Konkan (coastal) tract is the months of April, May and June, when all trees start new growth, just before the break of the monsoon.

Growth at this time also gives the scions which "take", the benefit of the following monsoon months to develop themselves. In Kaira district seventy per cent. success is said to have been obtained in side-grafting mango trees.

An interesting method of side or stem grafting of scion to the stem of old tree is successfully practised in South Kanara district of the Madras Presidency and is known by the popular name of 'insertion.' Trees having smooth trunks of less than two and half feet in diameter are selected and a triangular patch of bark two inches by two inches is removed on the part intended to be operated upon. Immediately below the lower corners of the triangular patch, two slits—two to three inches long—are made on the bark downwards. Well matured terminal shoots of six inches to eight inches in length and of the previous season's growth are selected from the scion parent, defoliated, and inserted carefully within the slip of bark lifted from between the longitudinal slits of bark already made, after paring off the lower one and a half to two inches of the scion shoot into the form of a wedge. The triangular piece of bark originally removed may or may not be replaced in its former position. The scion is held in position by firmly tying it to the trunk and a grafting wax made by melting together three parts of rosin, two parts of bees wax and one part of cocoanut oil (by weight) is applied over the bandaged parts after cooling. Four to six scions are thus inserted all round the tree, and when a large number of these show signs of active growth, a few main limbs of the tree are removed and within about six months, all the top portions of the rootstock tree are cut off and the wounds besmeared

with coal tar, and the tree earthed up close to the lowest scion. The operation of grafting is done during the monsoon from June to December, but many growers are of the opinion that August to December is the best season. Since this method is successfully practised only in places subject to heavy precipitation and high atmospheric humidity, it is doubtful, if it will lend itself for adoption in all the mango growing tracts. It is, of course, a useful method in the coastal regions of Western India from the Malabar coast to the Gujerat districts, where conditions of rainfall and humidity are identical.

Spring budding is also practised in the United States of America on young rootstocks. In top-working old mango trees by this method half or more of the main limbs are cut back to short stubs during the autumn. In the following spring or summer, the sprouts that start from these stubs are budded by first cutting off the shoot squarely a few inches above the base. The bark is then slit downward from the top of the shoots for inserting a shield bud tapered to a thin edge on the side only. The scion is carefully wrapped with a wax cloth and a light coat of melted but cooled paraffin applied over the scion. A paraffin paper bag is then tied over the entire end of the stock so budded.

Top-working can be done by ordinary budding also. The economic advantages of top-working may be gauged from the fact that a tree about thirty years of age worked upon in 1913 began to bear in 1916 and yielded fruits as follows (22):—

	Fruits No.
1916-17	38
1917-18	372
1918-19	450
1919-20	nil
1920-21	200
1921-22	350
1922-23	500
1923-24	450

Mango grafts commence bearing in their fifth or sixth year. Grafts of some varieties have been known in South India to

bear fruit in their third year and a few even in the second year. Seedlings take a much longer time, although sometimes even they are known to commence bearing in their fourth or fifth year. A normal crop may be expected from grafts when they are about fifteen years of age. Bearing increases with the advance of age until the trees grow fairly old.

Harvesting of mango fruits

Mango fruits of grafted varieties are usually harvested before they are ripe on the tree. The exact time of harvesting is judged by personal experience, although generally the fruits are supposed to be ready for harvesting when a few of them fall from the tree being naturally ripe. There appear to be two reasons for the harvesting of mango fruits while still green. Firstly, the fruits improve in sweetness and general quality by storing for a few days after harvesting, and secondly considerable damage is done by insects and birds to them if left on the tree until they are fully ripe. When fruits are ready for harvesting, they are generally fully developed with their shoulders well formed and the surface more or less plump. The stage of picking varies considerably in different varieties depending upon factors like slight yellowing of the rind as in the case of the Alphonso variety, development of a warty surface as in the case of *Cawasji Patel* and *Pairi*, the appearance of a deep flush as in the case of *Shenduria*, etc. Whenever possible, it is better to pick fruits with about half to one inch of the stalk left on them.

The actual operation of picking is done with a hand tool, termed as a mango picker, which consists of a long thin bamboo to the slender end of which is tied a small net bag with a thin iron or bamboo ring at its open end. The picker is locally called *vedi.* Two flat iron or bamboo splits are so tied over this ring that they can easily catch the fruit stalk and break it. The fruit falls in the net bag by a slight pull. If the tree is tall, the man who picks has to climb on it to harvest fruits with the picker and a large collection bag. When three or four fruits are collected in the net, they are taken out and put in the bag. When the bag is thus filled, it is let down by means of a rope and emptied on the ground. The empty bag is then drawn up by the man for collecting a fresh lot of fruits. In the case of dwarf trees, climbing on the tree is not necessary and the fruits are picked by hand from the ground.

PICKING AND PACKING OF MANGOES IN THE RATNAGIRI DISTRICT. *Facing page* 98.

An American type of "fruit harvester", which has a clipper attached to the thin end of the bamboo at its base by a spring arrangement, is found very handy. It enables the harvest of fruits with a piece of stalk attached.

Ripening of mango fruits

When mangoes are picked, they are all taken to the store, where they are spread out on a thick bedding of green mango leaves and kept there for about two days. The store is usually a well ventilated place. If the fruits are to be despatched to distant markets for sale, they may be packed soon after harvesting, so that they have time to reach the market before they ripen. For local markets, however, fruit is sent after ripening in the store, that is, when it is almost ready for the table.

For ripening, fruits are spread on rice straw in layers one upon the other, each layer of fruits being separated by a thick padding of straw. Generally, two or more layers are heaped in a single pile and such a pile is locally called an "*Adhi*". It is perhaps preferable to have a single layer of fruit covered completely with a thick layer of straw. The rice straw is soft and does not injure the fruits and, therefore, permits them to retain a good appearance for the market. Other kinds of straw, for example, *Iseilema Wightii*, called "Sona" in Marathi, are also used, but only for inferior mango fruits. The straw bed gives enough warmth for the fruit to ripen, which process in the case of most varieties takes about a week. If the fruits are spread uncovered, the ripening can be delayed considerably to suit market conditions. Ripening in straw beds is considered also necessary to develop attractive colour for the market. The fruits are ordinarily hand graded before they are displayed for sale.

Regarding the keeping quality of mangoes, Burns and Prayag (25) report that in an experiment which they carried out under room temperature, the *Pairi* fruits kept well for about a fortnight, and the Alphonso fruit for about twenty-five days, the fruits losing about twelve to eighteen percent of their original weight during the process of ripening. It is the common experience that the Alphonso keeps well in Bombay for about twenty days and the *Pairi* for eight to ten days. They also mention a trial wherein waxing of the stalk end of the fruit had no effect on the ripening.

Patwardhan (114) who carried out a study of the chemical

changes taking place in the mango fruit during the ripening process, states "from the temperature record, it can be seen that as the days proceed, the temperature slowly rises (in the *Adhi*) and goes as much as 8°C to 10°C higher than the room temperature. It has been seen that when the temperature goes above 36°C, mangoes become over-ripe and begin to rot very rapidly. When it goes to about 33°C or so, that is, on the fourth day of the *Adhi*, they are removed from the pile and made to ripen slowly, by keeping them uncovered on hay in single layers."

He further states that in the beginning, the change in the colour, smell and taste is slow, but after the fourth day it is very rapid, and may be complete within the next two days or so. It is observed that the amount of acid contained in the different varieties of mango is different. It may, however, decrease to about twelve percent of the original raw sample when fruit is ripe, but ordinarily it remains at about twenty-five to thirty-five percent of the original sample. The sugars increase rapidly in the beginning of the ripening process, the increase being gradual later on. Non-reducing sugars increase from 50 to 65 percent, while reducing sugars from 1 to 5 percent only. It is clear that when the juice is preserved in cans there is very large increase of the reducing sugars, owing to the likely inversion taking place.

Ontogenetic stages of maturity of mangoes

There are four distinct stages of the maturity of mangoes, that is the juvenile stage, the adolescent stage, the climacteric stage and senescent stage. The juvenile stage is the period from fertilisation for about twenty-one days. It is marked by a rapid cellular growth, high respiratory activity and high water content. The C/N (carbohydrate: nitrogen) ratio is low. The adolescent stage is the period between twenty-one and forty-nine days. It is marked by the maximum growth, development of aroma, and medium respiration. The C/N ratio increases. The climacteric stage is the period between forty-nine and seventy-seven days and is a critical stage. Respiratory activity is slow, and sucrose is medium. The C/N ratio is high. The senescent stage is the period from seventy-seven days onwards. The rate of respiration increases with an abrupt decline in sucrose and increase in glucose. The C/N ratio goes very high.

The system of marketing these fruits in the Bombay Presi-

dency, and in fact, all over India, has been very unsatisfactory.

Marketing of mango fruits

The result is that considerable loss occurs by spoilage due to bad handling and defective grading and packing. Enquiries made by the Mango Marketing Committee appointed by the Government of Bombay, in 1925, led to investigations and devising of certain practical measures towards improving the situation, and valuable results are now noticed in this regard (138). The course taken by mangoes from the grower's field to the consumer's table as it happens at present is interesting. A study of this course shows the following stages of preparation and progress:—

1. Picking and packing.
2. Journey by road to the railway station or to the port wharf (*bunder*).
3. Journey by railway or steamer.
4. Journey from railhead or wharf to the market at the market end.
5. Display and grading at the market.
6. Disposal—wholesale and retail.

Not infrequently, the grower sells his crop standing on the trees to local contractors called *Bagwans*, who are then responsible for the picking, packing and despatch of the produce. Whenever the sale of standing crop does not take place, the grower sends his fruit to the market himself. In both cases, however, the picking operation does not receive much attention. Mature and immature fruits are often picked together and physical injury to them is not uncommon. While packing, hardly any grading or sizing is done; what little sorting is done, is designed to place the best few fruits on the top of the package. Small fruits are placed at the bottom, medium at the centre and large at the top. All these sizes get usually mingled up when the packages are opened and emptied in the market. The most common containers are bamboo baskets which are flexible and fragile and liable to serious damage in transit besides being very inconvenient for handling and storage. In some progressive tracts, as in the case of the Ratnagiri mangoes these baskets are gradually giving place to wooden crates. The majority of mangoes are, however, still being packed in bamboo baskets of varying

sizes and shapes and are subject to considerable damage and loss during transit. The handling of the packages while loading, stacking, and unloading in carts, railway trains and steamer holds, is rough and crude. On arrival at the market, the commission agent to whom the parcels are consigned, often plays the jobber, opens several packages, sorts the whole lot according to the market requirement and sells the different lots to different classes of retailers and hawkers. Very often the wholesale transactions take place under cover, by taking bids or offers under cover of a piece of cloth so that none except the buyer who makes the bids and the commission agent can have an idea of the price offered and accepted. Open auction sale is a rare exception. After the wholesale transaction is over, the commission agent prepares his account for the consignor, and sends him the balance of the price realised after deducting his own commission charges and other market expenses. These expenses are divided under several heads, including ground rent and charity charges, and almost each head leaves ample room to the commission agent to swell his own net income. The consignor in the village has to content himself with whatever is sent to him by the agent, who happens to be the sole representative at the distant market. Retailing at the market is in the hands of stall holders, street corner shops and hawkers. Often the wholesaler is also the commission agent and *vice versa* and may also have his interests in the retail trade. Such is the complexity of the distributing organisation of fruits in this country. The situation is rendered still worse to the detriment of the grower by the absence of proper transport and storage facilities as well as a system of check to prevent deceitful practices.

Investigations in the marketing of fruits

Realising the chaotic situation in agricultural marketing, the Royal Commission on Agriculture in India (1929) observed, "We have sought to make plain the extent to which the prosperity of the cultivator and his progress in agricultural efficiency depends upon sound marketing. It has been pointed out that comparatively little has been done by Government in India to assist the cultivator in his marketing operation." In so far as mangoes are concerned, the first enquiry of its kind was conducted by the Mango Marketing Committee appointed by the Government of Bombay in 1925. The investigations of this Com-

mittee were confined to the system of marketing mango in the Konkan districts of Kanara, Ratnagiri, Kolaba and Thana from where this fruit is chiefly shipped to Bombay. The Committee made a number of recommendations but the progress of implementing these recommendations was extremely slow. Later on, the Bombay Government appointed the Bombay Fruit and Vegetable Market Committee in 1933 to go into the fuller details of the problem. The Committee's report containing a very large number of practical suggestions for improvement, was published in 1934. An enquiry on the marketing of fruits, particularly mangoes, was also carried out in Bihar in the year 1935. Later on, in co-operation with the Provincial and State Marketing Officers, the Agricultural Marketing Adviser to the Government of India conducted a detailed all-India survey on the marketing of mangoes but the results of the survey have not yet been published.

Growers' organisations

These various enquiries and the published reports depict the deplorable and wasteful conditions of the system of marketing the mango fruits. It is, however, to be noted with satisfaction that on the strength of the recommendations of the Bombay Fruit and Vegetable Market Committee, the Government of Bombay have now appointed a Provincial Fruit and Vegetable Market Committee, practically on a permanent basis, to watch and guide the trade in the Province. Side by side with these sporadic studies, gradually circumscribing the conditions prevalent in most of the Indian Provinces, attempts to organise the growers are also being made. One of the chief factors which adversely affects the prosperity of the growers at present is the lack of co-operation and organisation among themselves. Primarily due to the ignorance of the growers and to the lack of a definite national policy in developing the fruit industry, the growers are carrying on their enterprise in a disconnected and individualistic manner. They have not yet been able to realise the benefits of concerted action. The Imperial Economic Committee appointed by His Majesty's Government in England observe in their report on the marketing and preparing for the market of fruit, "We are convinced that the whole tendency to closer organisation of fruit growers is desirable and indeed inevitable, and we would give general emphatic support to the principle of their

organisation in the overseas parts of the Empire. As an individual, he (the grower) is helpless against the great chain of organisations with which he has to deal with in the transport of his fruits by land and sea, the railway and shipping companies, and the marketing organisations which exist in the United Kingdom." The co-operative movement in India has rightly to be credited with the origin of the agricultural produce sales societies such as cotton and gur sale societies in various centres. The mango sale societies in the Ratnagiri and Dharwar districts are also working on co-operative lines. These societies have had considerable educative influence on the disorganised and illiterate peasants of the countryside and have gone a long way to impress on them the benefits of concerted action. Lately, provincial fruit growers' associations have sprung up in Bombay, the Uttar Pradesh, Madras and the Punjab, with a view to work for the betterment of the growers in these provinces. While the aims and objects of these bodies are varying to some extent, and though they are in infancy as yet, the problems they have almost invariably taken up to solve are those relating to the marketing of growers' produce. One and all have realised through bitter experience that the improvement of the economic condition of the growers depends upon a better system of the disposal of their produce based on more favourable transport facilities coupled with a more efficient and widespread distributing organisation.

Grading of mangoes

It has already been stated that ordinarily mangoes, like most other fruits, are packed in fragile bamboo baskets without proper grading except "topping" the basket with large fruits, and placing smaller and inferior ones at the bottom. This practice has naturally destroyed the confidence of the consumers. Combined with rough handling during transit, the prevalent practices have brought down the price of the pack very considerably. The investigations carried out by the Bombay Department of Agriculture, published in their leaflet No. I of 1931, have shown that if mangoes of the Alphonso variety are graded carefully according to suitable standards, before packing for the market, a net gain as a result of grading fruits alone over the ungraded lots is on an average Rs. 21-8-0 per 1000 fruits, after deducting all extra charges involved in the grading operation. The three grades found suitable for certain varieties are:—

1st *grade* with fruits, weighing 28 tolas and above,
2nd *grade* with fruits weighing 24-28 tolas and
3rd *grade* with fruits weighing 18-24 tolas.

The average proportion of fruits of these three grades in an ordinary mixed lot works out at 150, 450 and 400 respectively, and each grade by itself brings a much higher price than the immediate lower one. This fact has been appreciated by the growers and consignors who are now taking up the grading of fruit rapidly in their commercial practice with evident advantage. An act to provide for the grading and marketing of mangoes known as Agricultural Produce (Grading and Marketing) Act, No. I, 1937 was passed by the Government.

Packing of mango fruits

Until lately, the fragile bamboo baskets have been shown to be a source of frequent loss on long journeys due to unsatisfactory handling. It is also insecure. To find out the efficacy of bamboo baskets as compared with suitable wooden crates or boxes, an attempt was made to send actual consignments in both types of containers from Ratnagiri to Bombay. These showed that:—

1. The average loss due to damage and pilfering came to 3·9 percent of fruits packed inboxes, while in baskets it came to 16·1 percent. Thus the loss in the case of baskets was five times greater than it was in the boxes.
2. The average gain in price per 100 fruits in wooden containers over the same number in bamboo baskets varied from Rs. 2-10-0 to Rs. 6-4-0 according to the price fluctuations in the market.
3. A wooden case can be used at least four times in the season, while the basket is used only once.

The cost to get back the empty cases from Bombay to Ratnagiri, a distance of about 120 miles by sea, is of course fairly great. But even then, packing in boxes would pay under items 1 and 2. Experience shows that the proper thickness of the pieces used for boxes is half an inch and their dimensions externally 20 inches and 15 inches. The capacity of such a box would be to hold 100 to 115 Alphonso fruits. The holes for

ventilation made on two sides of the case are half an inch in diameter. Coir rope handles are fixed on two sides for easy handling, and hinges are fixed to the lids. The boxes are fastened by wire and sealed with a plier. The total weight of the box after full packing should not exceed eighty pounds for easy handling. The chief difficuly in adopting packing improvements for general use is that, suitable wood for making packing cases is not cheaply available and that, until such cases can be manufactured on a mass scale they would not be cheap. The transport companies also should show material concession by carrying back empties at a nominal rate in the larger interest of the trade. At present, a light type of wood, namely, *Sayari* (*Bombax Malabaricum*), is being used for this purpose, and a few private concerns have taken to manufacturing the cases in the Ratnagiri district. It will, however, take some time before the boxes come into general use.

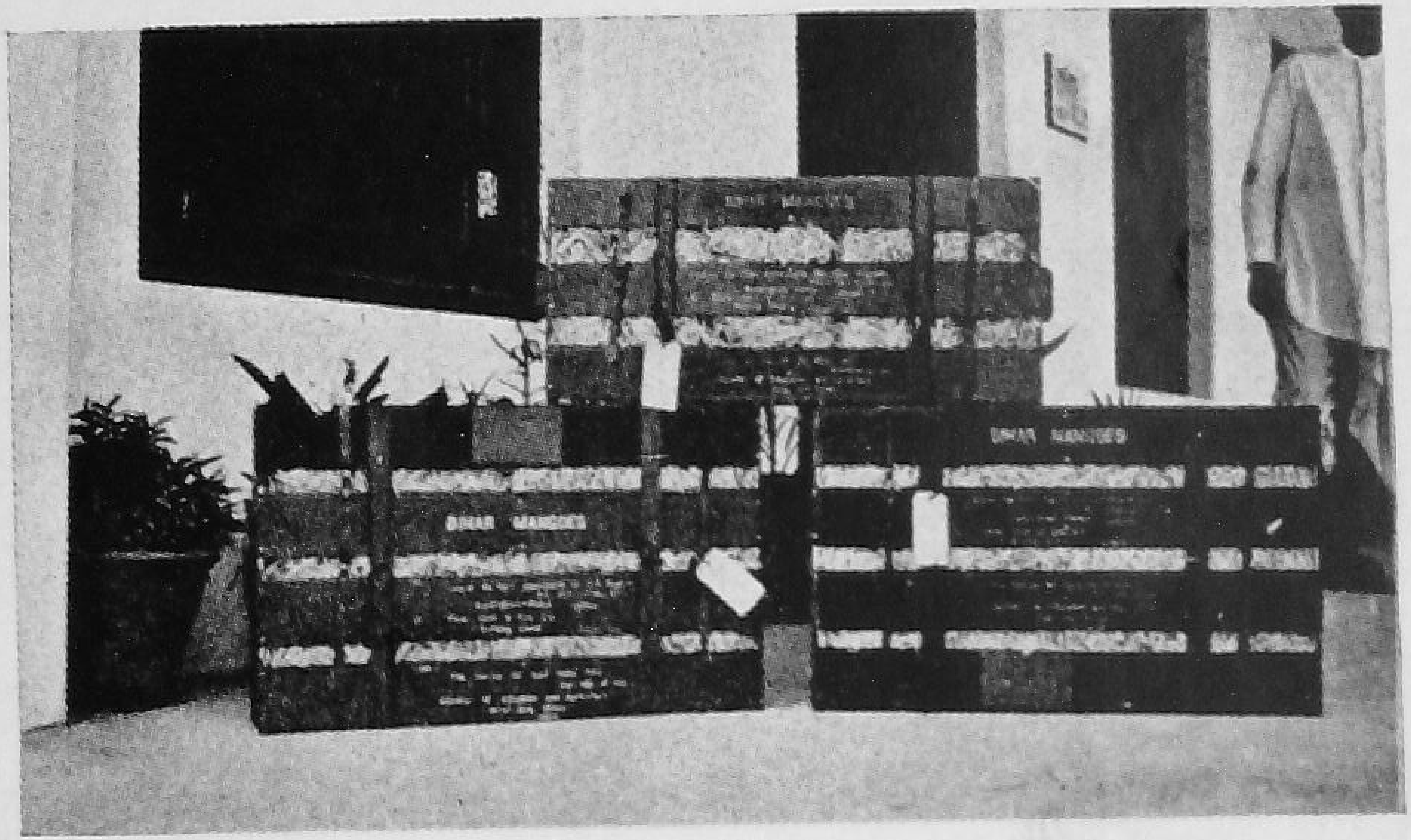
In Florida, a patented crate resembling a modified type of the box used for oranges and with a central compartment holding ice, is reported to be used by some people to guard against losses in long distance transports. Wardlaw and Leonard (184) consider that a standard twenty pound tomato box (5 by 16½ by 17 inches) packed in one or two layers, will be suitable for mangoes. Smith (161) on the other hand, suggests two sizes 17½ by 11½ by 5½ inches, and 17½ by 11½ by 4½ inches. The fruit sizes of cultivated varieties in India are so varying that the optimum size of package for each variety has still to be worked out.

From the Madras State, very large consignments of *Bangalora* (syn. *Totapuri* or *Collector*) are loaded in wagons and sent without any packing to Calcutta, Hyderabad (Deccan), and the Bombay Presidency. These fruits stand considerable careless handling and are good shippers and, therefore, they can stand such transport to an extent. But it will mean a great loss to the growers as well as consumers if attempts are made to send other delicate and superior varieties by this method.

After a long period of preliminary trials carried on in Bombay on the keeping quality of mangoes, an attempt was made in the years 1932 and 1933 (27) to export this fruit to Europe with a view to expand the market for it. The Alphonso or the Bombay mango was selected for this export, because of its attrac-

PACKING OF BOMBAY MANGOES FOR EXPORT BY STEAMER JOURNEY.

Facing page 106.



PACKING OF BIHAR MANGOES FOR EXPORT BY AIR.
(*Courtesy* : A. Aziz, Esq., Ex-Minister For Agriculture, Bihar and Orissa.)

Facing page 107.

Export of mangoes to Europe

tive appearance, medium size, fibreless pulp of good taste and consistency, high quality and reputation of keeping well even under ordinary conditions of temperature. This variety is also cultivated on a fairly large scale, and hence it is available in large quantities for the export trade. Great care was taken to pick the fruit at the right stage of maturity, namely, when it is about a week earlier than the usual picking time for local marketing, in order that the fruit might stand a long journey. This stage of maturity is now standardized and called the 'B' stage. The preparation of this fruit for export consisted of grading it in two classes—"Commercial I" and "Commercial II" with fruits weighing from 24 to 28 tolas and 20 to 24 tolas each respectively. These fruits were then packed in specially designed trays of light wood admitting free aeration. The fruits were wrapped in tissue paper and placed in two single layers at the rate of one dozen per tray. Five such trays were tied together to make a package for convenience of handling in transit. These packages were stowed in the "Pursers" cool room at a temperature of about 45°F, where they were observed to keep well for over three weeks. The packages were also properly labelled and consigned to the agents in England. Before stowing on board the steamers, intimation of the despatch of the consignment was given to the consignees in time. As a result, it was observed that the fruit can reach England, a journey of nearly three weeks, in very good condition, provided the temperature in storage did not vary much. The fruit also found ready market, but only when supplied in small quantities in England. The price fetched was on an average nine annas and six pies per fruit as against the total cost of exporting which came to five annas and six pies only per fruit. This showed bright commercial prospects in the year 1932. But when the consignments exceeded the market requirements in bulk in the year 1933, there was considerable despair and loss owing to the market being glutted. The result was that the price fetched per fruit fell very low, while the cost of export remained almost constant. Moreover, the difficulty of finding enough cold store space in the steamer holds also cropped up. The present situation is that, until these difficulties are overcome the export trade in this fruit has necessarily to progress very cautiously.

The storage of mangoes attracted the attention of workers in this country, more than a decade ago. Small lots of the Alphonso variety were stored for trial at various temperatures in a cold chamber in Bombay and the result was found to be encouraging (28). The fruit kept well for over a month at a temperature of about 40°F in the preliminary trials, where the control of a proper temperature was difficult as the chambers could not be exclusively reserved for this work. However, in the interest of the trade, it was found necessary to work out the exact keeping quality and the optimum temperature required for each of the more important commercial varieties of mangoes in India, including the Alphonso. With the help of the finance made available by the Indian Council of Agricultural Research, it was possible to work on this problem and several varieties were tested at the cold storage station, Ganeshkhind, Poona. Out of the several varieties tested for their commercial storage qualities the Alphonso was found to keep for fifty to sixty days at 48°F, when picked at the 'B' stage of maturity. The varieties tested among others were the *Suvarnarekha*, Alphonso and *Pairi*. The results already obtained with the Alphonso mango were confirmed and the influence of local conditions of soil, climate, cultivation, etc., on the storage quality of the fruit produced was also determined. The successful development of the export trade of India in mangoes should be fostered as a result of these experiments.

Cold storage of mangoes

The technique of gas storage, using chiefly carbon dioxide has been developed to a great extent in England and elsewhere. In India, trials on the gas storage of mangoes was undertaken along with the cold storage trials at the Ganeshkhind Fruit Experiment Station, Poona. The results were not very encouraging.

Gas storage of mangoes

Six important varieties of mangoes were analysed in Java (30). The average weight of fruit and the percentage of pulp are compared with those of the foreign mangoes, which possess a weight of 350 grammes, and 70 percent or more of which is pulp. Along with finding the chemical analysis of the fruit, the skin of the mango was also analysed. Javanese mangoes contain as much crude fibre as is contained in the Alphonso. These varieties equal Alphonso

Chemical analysis

Nutritive value of Indian mangoes

NAME	Moisture %.	Protein %.	Fat (Ether Extractives) %.	Mineral matter %.	Fibre %.	Carbohydrate %.	Calcium (Ca) %.	Phosphorus (P) %.	Iron (Fe) mgs. %.	Calorific value per 100 gms.	Carotene (International units per 100 gms.). Vit. A.	Vitamin B_1 (i. u. per 100 gms.).	Vitamin C mgs. per 100 gms.	Calories per ounce.
Mango, green	90·0	0·7	0·1	0·4	..	8·8	0·01	0·02	4·5	39	150	..	3	11
Mango, ripe	86·1	0·6	0·1	0·3	1·1	11·8	0·01	0·02	0·3	50	4800	..	13	14
Mango, Kala Ishad Ankola	85·9	1·0	0·1	0·5	..	12·5	0·01	0·02	0·5	55	1860	..	24	16

in regard to total sugar (13·1 to 16·8%) and sucrose (9·7 to 12·8%).

Mineral constituents

Determinations by Chace in the pulp of French and Filipino mangoes and a third variety not specified show 0·53, 0·41 and 0·78 percent of ash. Analysis of the ash appears below:—

	K_2O	CaO	MgO	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%
French	47·37	6·38	1·62	6·49	3·67	—	3·88
Filipino	51·79	1·74	3·25	9·04	4·88	1·75	1·56
Var. unknown	49·37	2·38	—	5·57	3·84	2·14	4·20

Mangoes have a high sugar content. They are rich in vitamins. The amounts of vitamin A and C apparently vary a great deal in the different strains. The deep yellow colour of the flesh of the Manila fruit suggests a rich A content. Crawford and Perry (34) found one variety as high as good butter, other varieties showed about half this value. They examined vitamin C potency and found values in different species varying from nothing up to twice the content of lemon.

Mitra and his co-workers (94) found mango (Aam Bombai) to contain 6.0 mg. Carotene and 10.5 mg. ascorbic acid per 100 gm.

Daniel and Munsell found ascorbic acid content of mango as per table given on page 111 :—

Ascorbic acid content

(Table on page 111)

(Values expressed as milligrams per 100 grammes)

Food value

Besides being a very delicious fruit, rightly called the king of fruits, mango has a high nutritional value. It is rich in Vitamins A and C. The pulp of the Alphonso variety is one of the most potent sources of Vitamin C. It is reported by Perry and Zilva (116) to be

Food	Description	Quantity of ascorbic acid: Dye method	Quantity of ascorbic acid: Iodine method	Year reported	Investigator
Mango (*Mangifera indica*)	Pulp	13	..	1935	Ahmad (2)
	Pulp, different graft from above	15·3	..		
	Green	3·2	..		
	Green, Bengali Deshi variety, Kancha	5	9·7	1935	Ghosh and Guha (54)
	Ripe, Bengali Deshi variety, Paka	2	4·4		
	Ripe, Fazli variety	34	44	1935	Ranganathan (134)
	Ripe, Langra variety ..	69	88		
	Green, very tender, pickled in salt	176·5	..		
	Dried, pickled in salt ..	2·6	..		

Average composition of the edible flesh of mango according to Winton and Winton (191) is as below:—

	Solids Total %	Solids Insol. %	Protein	Acid % (citric)	Invert Sugar %	Sucrose %	Ash Total %	Ash Alk.* %
Mango ..	16·76	1·76	0·43	0·39	3·56	10·06	0·47	47

*Ml. 0·1 N acid per 100 gm. fruit

According to Sherman (157) the average composition of fresh fruit is as follows:—

As purchased	Edible portion						
						Fuel value	
Refuse	Water	Protein	Fat	Carbo-hydrate including Fibre	Ash	per 100 grammes	per pound
%	%	%	%	%	%	Cals.	Cals.
34	81·4	0·7	0·2	17·2	0·48	73	335

HOME CANNING OF MANGO: ESSENTIAL EQUIPMENT.

(*Courtesy* : S. N. Venkatraman.)

Facing page 113.

much richer in vitamins A and C than many fruits normally considered good sources of these vitamins. The *Cawasjee Patel* variety although slightly less active, is as potent as the previously known natural antiscorbutic source. The *Shendrya* variety contains comparatively smaller amounts of vitamin C. The pulp of all three varieties contains vitamin A in quantities similar to those possessed by butter. The Alphonso variety is somewhat better than the other two varieties in this respect. Further trials did not indicate any significant results as to whether the maturity factor had any bearing on the vitamin content of the mango. Guha and Chakravarty (59) have also found that Indian mangoes are a fair source of Vitamins B and C, and a good source of G (B2). Mangoes possess a high sugar content, but they are poor in calcium, phosphorous and iron. This fruit, therefore, deserves to be very highly valued and should have a great future in the world market.

The composition of the edible fruit flesh of mango grown in West Indies is well illustrated by 4 analyses made by Cousins and 9 analyses made by Chace, Tolman and Munson. Pratt and Del Rosario made 3 analyses, of fruit grown in Philippines, and Thompson, 8 analyses of fruit grown in Hawaii. Results are given on page 114.

Canning of mango

The mango crop is in season for about two months only in the Bombay Presidency, during which period the fruits glut the market considerably. The growers do not realise a proper price for their crop and a good deal of waste occurs. Considering that this is practically a monopoly produce of this country, there is no reason why it cannot be packed in cans for marketing even to distant countries. The possibilities of developing the mango canning industry have been explored by some. Private organised effort is, however, necessary to place this line of work on a sound footing.

It is chiefly the superior table varieties of mango, which are used at present for canning. Factories in the North Kanara district use the *Kala Ishad* mango for this purpose. This variety is a very poor keeper, though of very high quality and is therefore most suited for the canning of mango pulp. In Ratnagiri and Bombay the Alphonso fruit is used for canning. The *Pairi* fruit has a pulp of soft consistency and may also lend itself to canning. But the most appreciated canning variety in the

Average composition of mango flesh

	Flesh in fruit	Solids Total	Solids Insol.	Protein	Fat	Acids as citric	Sugars reducing	Sucrose	Fibre	Ash total	Ash Alk.
	%	%	%	%	%	%	%	%	%	%	CC.
Cousins											
Aver.	58	18·80	1·02	..	..	1·44	3·72	8·81	..	0·32	..
Chace, Tolman and Munsom											
Aver.	63	16·76	1·76	0·43	..	0·39	3·56	10·06	..	0·47	47
Pratt & Del Rosario											
Aver.	69	22·30	4·50	0·73	..	0·27	3·27	12·60	..	0·46	55
Thompson											
Aver.	64	20·07	3·44	0·71	0·15	0·42	3·16	12·09	0·59	0·39	..

Bombay Presidency is the Alphonso which can be sliced and canned in syrup.

Canning of mangoes is not difficult even on a home scale. The process consists of extracting the pulp of the variety selected, removing the skin and stone. As yet no efficient mechanism has been devised for extraction of pulp and stone. The pulp is then filled into sterilised and preferably lacquered cans, upto about half an inch from the brim. The lid is then placed on the filled can and is partially seamed with a hand or power machine. Cans so closed are then made to stand in a water bath, taking care to see that no water enters them or splashes inside. It is also possible to drive out the air from unseamed cans. The water is kept boiling for about seven to ten minutes, and when the free as well as dissolved air inside the cans is driven out by the heat produced in them, the cans are taken out of the bath and finally seamed air-tight when still hot. They are then placed in the water bath once again, this time immersing the cans completely in water, which is boiled for about thirty minutes depending upon the size of the can. The first heating is called the process of "exhausting", because at that time all the air inside the cans is driven out, and the cans are exhausted. The second heating is called the process of "sterilising" or "processing" because the contents of the cans are sterilised by killing all the harmful organisms in them, which if retained would bring about the spoilage of the cans. After sterilisation the cans are immediately "chilled" by throwing them in cold water, so as to prevent over-cooking of the contents. The cans on cooling are stored in a cool place until they are required for sale or despatch to another place.

At Kodur in the Madras Presidency, it has been found that exhausting need not be done for more than ten minutes, but in this case the lid is not placed over filled cans. The lids are seamed soon after ten minutes exhaustion, and processed for twenty minutes, and subsequently chilled in water. Canned mango pulp and slices, subjected to these treatments, have preserved their natural aroma and flavour of the fresh fruits to a very great extent, and on bacteriological analysis after six months storage showed no trace of any harmful organisms. Since the quality including the value varies markedly in different varieties of mangoes, a uniform procedure to be

adopted in the canning of each of the several well-known Indian varieties has yet to be worked out to effect standardization of the ultimate product.

The preliminary trials on the suitability of a number of mango varieties have, however, shown that for the production of best canned mango pulp, a variety should be slightly juicy, should possess a strong and pleasant aroma, bright coloured pulp, and be free from stringiness. Some of the seedling types of mango, though valueless as table fruits, because of small size and big stones, were found to be very suitable for this purpose at Kodur.

In the case of mango slices, the fruit is peeled and two broad slices are taken from the two flat sides of the fruit while two narrow slices are taken from its narrow sides. These slices from one or more fruits are filled in neatly into the cans. Sugar syrup of the strength of 25-27 percent, is poured into the cans to fill in all the interspaces of the slices up to about half an inch from the brim of the cans. The cans are then subjected to exhaustion and sterilisation as above. They are then stored away in a suitable place.

It may be advantageous to can only slices of uniform shape and size to produce cans of graded quality, and for this purpose to separate the slices from flat sides from those obtained from narrow sides of fruits. The latter may be canned as pie. The mixed slices, however, lend themselves for canning as fruit salads. An attractive and delicious salad would be a mixture containing mango, papaya and pineapple.

Grafted varieties of mangoes like *Langra*, *Safaida*, *Baneshan*, *Sandhuri*, *Dusheri*, *Saroli*, etc., may all be preserved commercially in the form of canned slices, which represent the nearest approach to the fresh fruit and can thus be made available during the off season. The stage of ripeness of the fruit when it is used for the purpose is, when it is just firm ripe, *i.e.*, neither too hard nor too soft—the actual canning stage being determined by trials and experience. One of the recommended commercial methods is to wash the fruit and peel it with a stainless steel peeling knife and cut into slices of the desired thickness which may then be immersed in cold two percent common salt solution. The slices are rinsed in cold water and packed in lacquered cans. Hot syrup of 35° Brix (prepared by adding 5·4 lb. of sugar to

SLICING OF RAW MANGO FRUITS FOR SALTING.

Facing page 117.

a gallon of water) is added to fill the inter-space and then exhausted in water for 12 minutes, followed by immediate cooling in running cold water, after which the cans may be stored in a dry place.

Salting of mango

Various other preserves of mango can be prepared with advantage using fruits at all stages of maturity. Pickle, chutney, jam, sweets of different kinds, drinks and dried mango pulp or mango leather are common in this country. Mango sauce and mango butter are some others among the vast variety of products that can be usefully made out of the raw and ripe fruits. Mango chutney, pickle and dried pulp are being prepared in several parts of this country as a cottage industry by various methods to suit individual taste. Salting of mangoes is chiefly done at *Rajapur* in the Ratnagiri district. Raw fruits of seedling trees are used for this purpose. Fruits are peeled, cut into small slices salted and packed into wooden barrels. The stones are thrown away. The peeling and slicing are done by women and children on contract labour. The barrels are sent to Bombay by small boats called *Machawas*. Each barrel contains five hundred-weight of slices. The slices are used for preparing chutney or *achars* (pickles). Similarly, large trade in brined mango slices exists in West Bengal and U. P. also.

Whole fruits of mango are also preserved in brine for use out of season. This is generally done in small quantities in earthen pots or wooden casks—either fresh or after being half boiled, the medium of preservation being about 15 percent strong brine. Such fruits last for some months.

Dried mango pulp, sometimes known as "mango sheets" is a favourite product prepared in many parts of the country. One of the methods of preparing this product is as explained below.

The clean and thoroughly washed fruit of the juicy variety—fully ripe with thick scarlet yellow pulp—is squeezed either with gloved hands or through a pulping machine followed by screening through a stainless steel sieve. The screened pulp is then spread in many thin layers on trays $2\frac{3}{4}' \times 2'$ covered with sheets of buttered glazed paper. The trays are then put in the sun for drying or for large scale production they are put in the Home-drier at 140°—150°F. The first layer of the juice having been dried, it is lubricated and another layer made thereon for

drying in the same manner. The process is repeated until a sufficiently thick layer ($\frac{1}{4}''$—$\frac{1}{2}''$) of the dried pulp is obtained. By exposing the product to sulphur dioxide fumes for 12-24 hours, the product can be made to retain the attractive golden colour and appearance for a considerable period without deterioration in quality.

Diseases and pests of mango

The mango tree suffers from several diseases and pests in Western India. Two among them seem to be more serious than others as they considerably reduce the yield. One is a pest, a mango hopper and the other is a disease, known as powdery mildew. Cloudy weather encourages their incidence of attack as well as the damage by them. The mango tree usually flowers in the Bombay Presidency in three flushes—the first appearing in November-December, the second in January and the third in February. The first flush is generally almost free from both the hoppers and the mildew. The second flush which appears in January and which is the heaviest of all is affected badly by the hoppers and to a slight extent by the mildew, whereas in the third flush the hopper attack diminishes but the mildew gets worse.

Mango hoppers

The hopper is a small wedge-shaped insect, belonging to the class of bugs (182). As soon as the blossoms appear, these tiny insects lay their eggs inside the bud. The eggs hatch in 4 to 6 days. The small wingless nymph, which emerges from the eggs sucks the sap from the flowers and tender fruits and develops into winged adults in ten to twelve days after casting four moults. The continuous drain of the sap by the nymphs and the adults leads to the premature dropping of the flowers and young fruits. Besides, these insects secrete large quantities of "honey dew" which cover the flowers and thus interfere with their development. The characteristic blackness of the flower buds and leaves in the affected gardens is due to the development of a black sooty mould on the sugary secretion. The winged adults are found resting on the shoots and leaves, and when disturbed, they jump and fly to neighbouring leaves causing a peculiar spattering noise, particularly when the attack is severe. The hoppers may destroy the entire crop, but usually the loss varies from 25% to 60%.

There are three species of hoppers, namely, *Idiocerus clypealis*,

I. atkinsoni and *I. niveosparsus*. Of these, the first is the most harmful and smallest in size. Uppal and Wagle (175) have described the life history and distribution of all the three species in the Bombay Province. Their nymphs suck sap from flower buds and flowers and cause severe damage. Dusting the inflorescence with sulphur of 300-mesh and then repeating the application at ten days' intervals gives satisfactory control. In Konkan and Karnatak where the sulphur-susceptible *I. clypealis* is prevalent, 3 to 4 applications will give effective control while 8 to 10 dustings may be required to control *I. niveosparsus* in South Gujerat and Bombay suburban area. Recently Trehan (172) found that dusting with 10% D.D.T. plus sulphur in the ratio of 1: 1 yielded very satisfactory control of this pest in the Bombay Province. Deshpande and Karandikar (41) state that spraying of a contact insecticide like the fish oil rosin soap (1 lb. of fish oil rosin soap to 4 gls. of water) controls the pest in the nymphal stage, but has very little effect on the adult. Trehan (172), however, noted that spraying with 0·2% D.D.T. proved very effective and economical.

Powdery mildew

Powdery mildew due to Oidium mangiferae is easily distinguished by a whitish coating on the affected blossoms, which appear as if dusted with white fine powder. The mildew makes its first appearance on the scales, fruits, buds of tender flower-heads, axils and stalks. The minute spores of the fungus are carried away by wind from the affected, flower-heads to the hairy unopened flowers, which thus become diseased. A fresh crop of spores is produced within five days from the time of infection. The process of spore formation and secondary spread continues as long as conditions are favourable. It can thus be seen how a few affected flowers and leaves can cause widespread epidemics under favourable conditions. The white appearance of the diseased blossoms is due to the fungus. The fungus feeds on the outer cell of flowers and very young fruits, which subsequently dry and drop down. Powdery mildew, though not as destructive as the hoppers, may cause a loss ranging from five to twenty percent, mostly during the months of February and March.

Sulphur dusting is the cheapest and most effective remedy against both the hoppers and mildew, as a deterrent against

the former and a preventive and curative against the latter but its residual effect is not much. In a bad case of hopper infection, however, it is more advisable to either spray with D.D.T. or dust with D.D.T.+sulphur or gammexene+sulphur which have a good residual effect as well as very high percentage of immediate knockdown. These treatments keep the insects away for a considerable period and only a few dustings are needed. It should, however, be noted that sulphur dust should invariably be 250-300 mesh fine as coarse sulphur has little fungicidal value. Dusting is best applied by the Peerless Dust Gun, which works well for trees 12-15 ft. in height. For taller trees, however, the use of a step ladder or extension tubes is found convenient.

The number of times it is necessary to dust sulphur will depend upon the season and the source of infection. However, in the coastal tracts, the following schedule of dusting has given the best results:—

1. The first application should be made soon after flowering. It is by far the most important as it is preventive against both the pest and the disease, and should, therefore, be done very thoroughly.
2. The second application should be made about 15 days after the first and may be followed by a third application. Care should be taken that a thorough application of the dust is made in each case.

By mixing D. D. T. or gammexene to sulphur, the intervals may be increased and the number of dustings reduced. The application may be repeated soon after the treatment if rain falls and washes the dust.

Dusting should be preferably done in the mornings when the wind is not strong because high winds result in waste of material, while a gentle breeze helps the operation. Still days are the best.

On an average 1-3 lb. of material may be enough for each dusting per tree. The cost of dusting sulphur including labour, comes to about one rupee but its mixture with D. D .T. or gammexene proves more effective though slightly more expensive.

While dusting sulphur or any mixture, the operator should work with his back to the wind because these insecticides cause

irritation to the eyes which should preferably be protected by goggles. If the eyes become inflamed, immediate relief may be obtained by washing them in a solution prepared by mixing a teaspoonful of soda bicarbonate (baking soda) in a large glass of water.

Stem borer

The stem borer (*Batocera rubus*) is a very common and serious pest of mango trees. The borer is a stout beetle grub which bores into the stem or a branch of the tree. Eggs are laid in chinks of the older barks and the grubs hatching bore into the stem and their presence can be noted by the frass coming out of the hole. The grub can be extracted by means of a thin hooked wire passed inside the gallery. If this is not possible, a small cotton plug dipped in carbon bisulphide, petrol or chloroform or a crystal of potassium cyanide can be inserted into the gallery and the mouth closed immediately with mud. Preferably, all the openings on a tree should be closed so that the grub feeding inside is suffocated to death by the vapours of the chemical used. All the trees in the garden should be treated together, and all the holes on the same tree should be inspected and treated as above. If the gallery is shallow, it can be opened and the grub scooped out without much difficulty. The injury caused to the trees in these operations, should be treated by painting it with coaltar.

Another borer—*Chlumetia transversa* is a major pest feeding inside the young growing shoots. In the rainy season young grafted seedlings are severely damaged and may even be netted. The tunnelled tender shoots drop off and dry at the end. Cutting the twigs below the tunnel and burning them reduces the attack in the next flush. Spraying with 0·5 percent lead arsenate at 3-4 days intervals on new shoots checks the attack considerably.

Leaf eating insects

Several types of caterpillars and other insects eat the tender leaves and shoots of young nursery plants. The greatest setback is received by the seedlings when their leaves are eaten away or cut by insects and drop soon after new sprouting. Occasional spraying with lead arsenate checks the ravages of these insects, and the young seedlings, are found to thrive better when thus treated. In Ceylon the young trees in the orchards are also subject to damage by weevils which attack young leaves. To control this

pest spraying with lead arsenate at the rate of one ounce to three gallons of water is recommended.

Another common pest is the fruit weevil, *Cryptorhyncus mangiferae*. The weevil is about $\frac{1}{3}''$ long, dark grey in colour, with darkish bands on *elytra*. The eggs are laid in the undeveloped ovary of a fruit, and the grubs bore into the stone where they mature. When the fruit is ripe, the weevil usually comes out of the stone and spoils the pulp. Some varieties of mangoes are particularly favoured. By way of remedial measures the affected fruits and stones should be burnt and the soil around the affected trees should be dug out to expose the weevils.

Mango stone weevil

Some mango fruits which appear quite sound from outside are found infested with maggots. The fruit-fly lays eggs in well-developed fruits, and the maggots spoil all the pulp. When full grown, they come out of the fruit and pupate in the soil. Four different species, namely, *Dacus ferrugineus*, *D. Zonatus*, *D. Correctus* and *D. ferrugineus dorsalis* infest these fruits, the first two being very serious.

Fruit fly

By way of control, all fruits attacked by maggots should be destroyed at night and some of the fallen fruits may be used as traps to induce the flies to lay eggs in them which may be easily destroyed. Clensel traps as suggested by Trehan and Pingle (174) may yield some good results in reducing the attack.

In Ceylon (108), the ripening mango fruits are pierced by a common fruit fly (*Chaetodacus ferrugineus*) which can be controlled by the following poisoned bait, prepared from:—

Lead arsenate	½ ounce
Jaggery (raw sugar)	12 ounces
Water	10 pints

This mixture should be placed in cigarette tins hung up on the branches. The flies are attracted to this bait and die. "Lure" cages are found useful for trapping flies.

Several types of scale insects are often found to attack mango leaves and fruits, and the insects can be destroyed by spraying the trees with fish oil rosin soap in the proportion of 1 : 40 parts of water.

Scale insects

The chief mango disease is the powdery mildew which has been dealt with along with the hoppers, as it is associated with

Fungoid diseases

them. The other diseases such as black stem and blight are controlled by spraying with Bordeaux mixture.

Anthracnose of mango caused by the fungus *Colletotrichum gloeosporioides*, is the major factor directly limiting the mango crop in Punjab and other parts of India. The disease attacks the more tender portions of the mango trees including flowers and fruits. It appears in the form of small black or dark spots on the stems, leaves and flower stalks. It spreads rapidly, flowers and flower stalks wither and the fruiting of the trees may be entirely prevented. With lighter infections on the flower clusters, some fruits may set, but later, the disease may spread to the peduncles and the fruits drop. Ripe fruits are also attacked and destroyed. To control the disease, about eight applications of Bordeaux Mixture (3: 3: 50) with a calcium caseinate spreader are needed. The first three applications are made to protect the flower clusters and the last five to preserve the newly set fruits.

The "anthracnose" which causes leaf-spots, blossom blight and fruit rot, can be controlled effectively by spraying the trees with one per cent Burgundy mixture, prepared in the field from concentrated solutions of bluestone and washing soda, diluted to correct strength properly mixed and promptly used. Weekly sprayings with Burgundy mixture have been markedly beneficial to control this disease.

In some orchards, young mango trees are found to wither from the ends of shoots which slowly darken and die downwards. In the Kathiawar area, such plants are also seen to ooze a thick gummy substance of deep brown or reddish colour, just below the dead portion particularly at the nodes and joints of old and new growths. This disease seems to be associated with heavy or over-irrigation combined with planting under shade. The trouble has not been investigated yet, and the remedy, as a first aid, appears to be to spray the affected trees with Bordeaux mixture, after the affected portion is clipped off and burnt. Frequent cultivation and clearing of shady intercrops and improved drainage may assist recovery of plants.

Loranthus is a parasitic flowering plant found growing on mango trees very commonly in this country. It is botanically named *Loranthus longiflorus*. There are several varieties of this

Loranthus

parasite, locally known as *Bandgul*, *Badanike*, *Bandalka*, or *Vandha*. Its branches are drooping and the leaves are thick, succulent and light green. The plant sends its roots (haustoria) into the tissues of mango (and many other host plants) and sucks the sap taken in by those plants from the soil. The sap is thus prevented from going above the point of attack. In course of time, the branch of mango above the point of attack by *Loranthus* dries up and if the attack is severe, the whole tree becomes weak and may succumb. The *Loranthus* itself, however, thrives and grows well at the cost of the host plant. The spread and infection by this plant takes place through birds eating its fruit and depositing the seeds on the branches where they perch. The seeds so dropped get firm hold on the branches, and germinate in course of time, when the parasite grows. The only effective remedy against this is to cut all infested branches well below the place of attack and apply tar to the cut end. If the attacked branches are large, the *Loranthus* can be scraped from the host stem and not allowed to grow again, by periodic inspection and removals. Large old mango trees are particularly seen to be badly attacked by *Loranthus* and require to be protected against this serious parasite.

Lichens

Several cases are noticed where stems of fairly grown up mango trees are badly covered with whitish superficial growth of lichens, especially in the heavier rainfall tracts. The infestation is all the more severe where the orchard is neglected and the trees are weak in health. The lichens perhaps do no damage to the trees directly.

Teratology of mango inflorescence

Occasionally, great abnormality is seen in the inflorescence of mango. They do not set fruits, but appear like longish vegetative brooms. The axes are shortened and thickened. The flowers are crowded, take long in opening, have often enlarged discs and seldom set fruits. The abnormal inflorescence may persist long after the normal one has fallen off the tree, and may finally become vegetative. So far, no cause for this malformation has been traced. It is, however, not due to either insects or fungus. The occurrence of malformation is more frequent in the Gujerat area than in other parts of the Province of Bombay.

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CHAPTER III

ORANGES AND ALLIED CITRUS FRUITS

Oranges and allied citrus fruits are perhaps among the most popular and extensively grown fruits of the world. The high medicinal and nutritive value attached to them have made these fruits almost indispensable in several parts of the world. Although these fruits are sub-tropical, they are also grown in most countries in the tropics and in some favourable parts of the temperate region. The commercial importance of these fruits is very great to every country which produces them. The world production of citrus is reported to be 230,000,000 boxes per annum, of which about 25 percent finds its way into export channels. In the States of Florida and California, where citrus cultivation can be said to have reached the climax of commercial fruit farming, the annual crops are said to have been over 134 million dollars in value in 1935.

Introduction

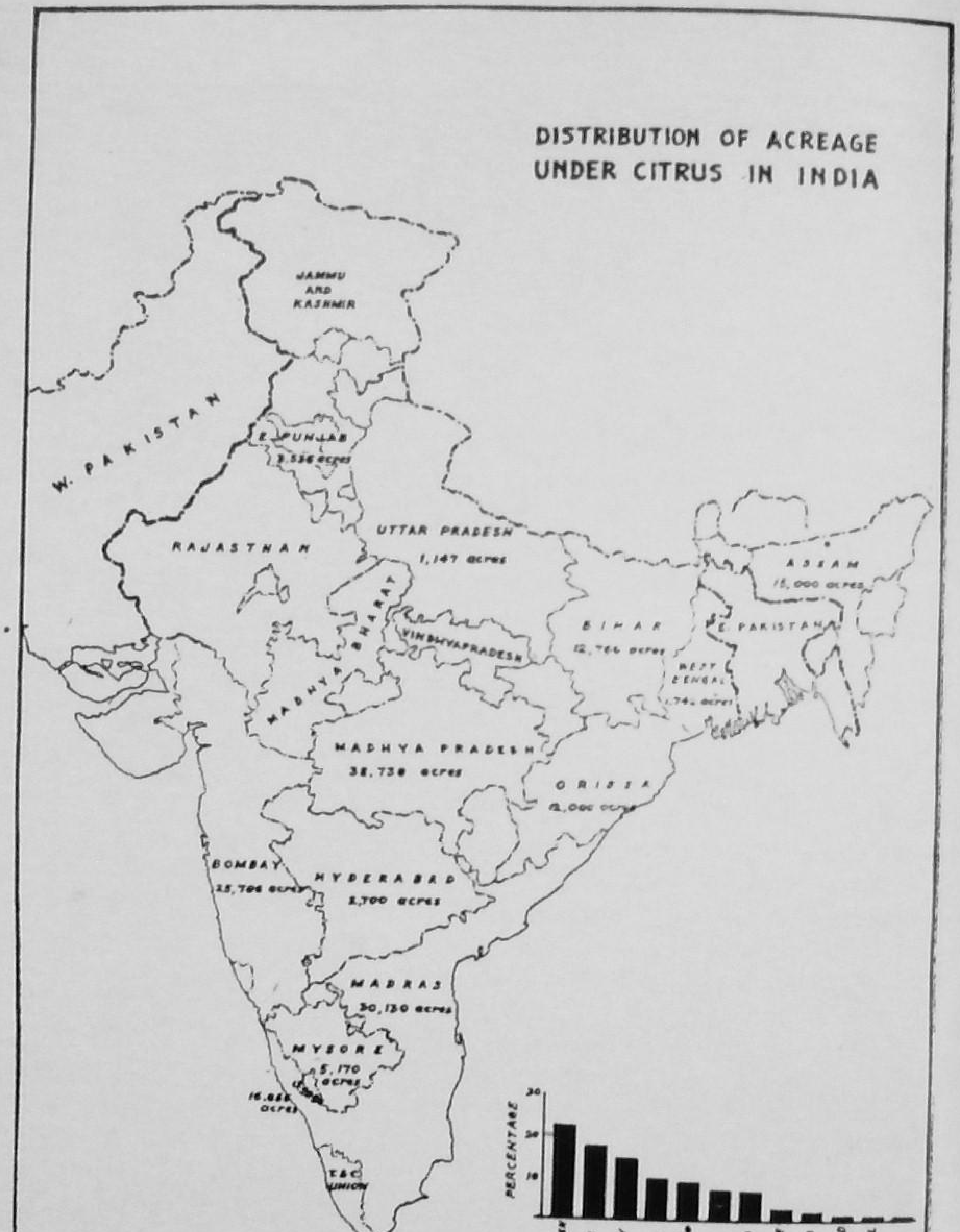
De Condolle (65) opines that citrus fruits must have originated somewhere in the north-eastern parts of India, Siam or Southern China. There is evidence to show that these fruits existed in these parts of the Asian continent in pre-historic times. It appears that the varieties of citrus slowly spread to European countries and the American continent comparatively recently. They are now grown in Italy, Spain, Palestine, California, Florida, Central and South America, South Africa, Philippines, Australia, Japan and China, where they have attained an indisputable commercial magnitude. Citrus growing is carried on in these countries as a very profitable industry, both for home consumption as well as for export of fruits and their products.

Origin and distribution

In India, the chief citrus growing provinces are Madras, the C. P., Punjab, Coorg, Mysore, the southern slopes of the Cherrapunji hills of Assam, northern Orissa and the Bombay Presidency. Practically, no part of India is left where one or the other variety of citrus has not entered into local importance.

A SANTRA ORANGE GROVE IN FULL BEARING.

Facing page 138.


DISTRIBUTION OF ACREAGE UNDER CITRUS IN INDIA
JAMMU AND KASHMIR
W. PAKISTAN
E. PUNJAB
UTTAR PRADESH
1,147 acres
RAJASTHAN
MADHYA BHARAT
VINDHYAPRADESH
BIHAR
ASSAM
E. PAKISTAN
WEST BENGAL
MADHYA PRADESH
38,738 acres
ORISSA
BOMBAY
HYDERABAD
2,700 acres
MADRAS
30,130 acres
MYSORE
5,170 acres
T&C UNION
PERCENTAGE
M.PRADESH
MADRAS
BOMBAY
COORG
ASSAM
BIHAR
ORISSA
MYSORE
E.PUNJAB
HYDERABAD
W.BENGAL
U.P.
TOTAL ACREAGE IN INDIA 1,68,570 acres

Area under citrus in India is 1,65,570 acres as per table given below :—

1.	Madhya Pradesh	38,738	acres
2.	Madras	30,130	,,
3.	Bombay	25,786	,,
4.	Coorg	16,855	,,
5.	Assam	15,000	,,
6.	Bihar	12,766	,,
7.	Mysore	5,170	,,
8.	East Punjab	3,536	,,
9.	Hyderabad	2,700	,,
10.	W. Bengal	1,742	,,
11.	Uttar Pradesh	1,147	,,

Cultivation in the Bombay Presidency

There are a large number of species of citrus found growing in the Presidency of Bombay. Their cultivation is mainly restricted to particular zones which are suitable from the point of view of soil, climate and other conditions such as facilities for irrigation. The important varieties of this Presidency are the oranges, a name by which both the *Santra* and *Mosambi* are popularly designated, the lime (*kagdi limbu*), the pummelo and the citron group. These varieties are not all found occupying the same zones. They are more or less severally distributed according to suitable conditions. In fact, the orange and the lime are alone cultivated on plantation scale. The other types are mostly seen scattered as individual trees in the regular plantations of oranges and limes.

The total area under citrus cultivation in the Bombay Presidency is nearly 35,701 acres (1947-48). The two types of oranges (*Santra* and *Mosambi*) alone occupy nearly 25,646 acres of this area. Then comes the lime (*kagdi limbu*) which occupies 2,656 acres on the whole. Its cultivation is more extensively distributed than that of the oranges.

Soil

The soil of this Presidency is so varying in nature that it is practically impossible to classify it correctly under definite heads, and accordingly to describe their nature in a general way. Besides a large number of distinct types of soils, there exists a great variety of shades in what may be

called the same kind of soil. The soil varies in character almost from field to field, and many times from plot to plot. The citrus trees are grown in almost all kinds of soils of this Presidency, from a heavy black soil to an extremely shallow open soil with little fertility in it. Some of the varieties of citrus seem to adapt themselves to soil conditions better than others. In the Poona and the Ahmednagar districts, there are places with a very deep sticky soil, wherein are cultivated *Santras* and *Mosambis* with considerable success. In certain other parts of the Ahmednagar district and the Dharwar district are places with shallow stony soil, where also the citrus plants are grown. The pummelo is grown in the Konkan tract where the soil is shallow and sandy. What is generally named as the *shadu* soil (a whitish limy soil, which does not allow a free drainage of water) is common in a number of districts and is found as a subsoil from one to two feet below the surface. In certain tracts it is also found forming the surface layer and runs to a greater depth. This soil is sticky in nature and has a larger percentage of lime going up to 15 percent. At Kohlar in the Ahmednagar district, an attempt was made by a cultivator to grow some trees of the *Santra*, the *Mosambi* and the *Kagdi limbu* varieties in a field where this *shadu* soil was found on the surface. The plants never thrived and ultimately all of them died in less than three years from the time of planting. However, when the subsoil layers are alone of the *shadu* type, the plants grow very well for a period of four or five years. But when their feeding roots tap the lower *shadu* layer, the trouble (chiefly in the form of die-back) begins. Similar is the case in other parts of the Presidency where citrus trees are grown in shallow soils with an underlying layer of rock or stone, which the roots of citrus plants cannot penetrate. While planting in such soils, pits of the size of about $3' \times 3' \times 3'$ are taken and filled with loose soil mixed with manure. Plants in such pits grow normally for some time and then suffer from die-back when their roots come into contact with the surrounding hard layer. This condition was actually noticed on the Kumta Farm in the Kanara district where *Santra* and *Mosambi* trees suffered even at the very early age of about six years. Indian soils in general are deficient in organic contents, and wherever this deficiency is not made up by an adequate supply of bulky manures, the citrus trees suffer for want of nutrition.

In short, citrus trees are seen to thrive well in well-drained soils such as the alluvial, medium black or loamy soils such as are found on the banks of rivers or *nallas*. A hard substratum or sticky subsoil is deleterious to the health of these trees. In the Bombay Presidency, the medium black soil of Poona, Saswad and other places, the reddish, whitish or brown alluvial soils on the banks of rivers and streamlets and the loamy or *goradu* soils of Gujerat are considered well suited for growing oranges and allied fruits. In the Deccan, black or medium black soils about two or three feet in depth with murum or sand below can be selected for planting citrus trees. A high lying site in such soils may be preferred, because, however suitable the soil itself may be, there should be no chance for it to be submerged by floods in the rainy season lest the trees suffer. A high lying site has also the advantage of natural drainage.

Soils characterised by a high percentage of sand and a negligible quantity of clay are almost always regarded as unsuited for citrus cultivation in California. Water percolates easily in coarse soils carrying with it the finer particles, and leaching a large part of the more easily soluble fertilisers. A survey of Valencia orange groves in the United States of America revealed that orchards located in good medium loamy soils give best production and income (335). In Palestine the best soil for citrus cultivation is considered to be the one containing a medium amount of loam (193).

The presence of a high water table renders the site unsuitable for citrus trees. Although the optimum depth of the water will vary in different soils and locations, it is safe to state that any soil which has a water table nearer than six feet from the ground level is unsuited for citrus cultivation. Not only the permanent water table, but it is the fluctuating table also that causes considerable damage to the roots.

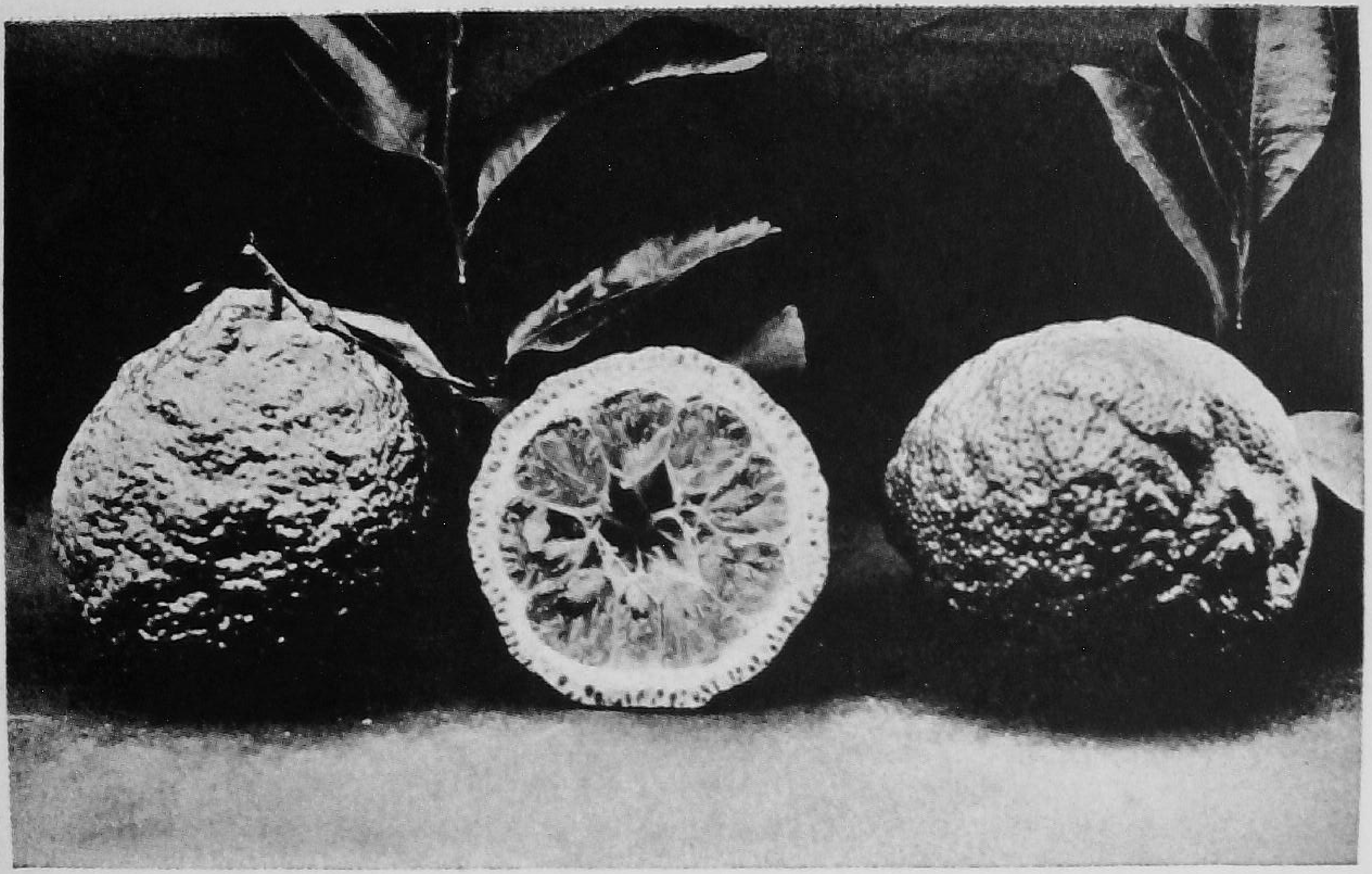
Citrus trees are quite sensitive to alkali and especially to sodium chloride (140). Irrigation waters containing sodium chloride should, therfore, be strictly avoided. Flood or some form of basin irrigation may be adopted where saline water is the only irrigation supply in order to effectively leach the salts down into the subsoil. Reed and Haas (207) have shown that while the presence of calcium salts was necessary for the successful growth of young orange trees, and serious injury occurs to trees

in the absence of these salts in the soil the absence of potassium salts did not produce any marked ill-effects. A good soil was associated with relatively high calcium especially in the root zone and relatively low sodium content, and the poorest soil with relatively low calcium and very high sodium content. The sweet orange is adapted to deep light soils of basaltic nature and gives much greater longevity when used as a rootstock. For grapefruit and lemons, the common lemon is recommended as a rootstock in such soils (342).

Citrus trees in general are not seen to thrive in heavy rainfall tracts like the Konkan. *Santras* and *Mosambis* do grow well for some years in a rainy and moist tract, but they do not fruit well. A drier climate with an annual rainfall up to thirty inches as is obtained in most parts of the Deccan is better suited to *Santras* and *Mosambis*. In well-drained lands or on hill slopes, like those in Coorg, the *Santra* oranges tolerate a high rainfall, exceeding even 100 inches per annum. Within reasonable limits, it would seem that it is not so much the actual quantity of rain that falls, but the distribution of that quantity and the facilities that prevail for drainage which matter. The *Santra* requires in Bombay Presidency even a drier climate than the *Mosambi* does. This is seen as one proceeds towards the east of the Deccan plateau where *Santra* plantations thrive better than on the borders of the Ghats towards the west where the rainfall is more and the climate is moister. The *Mosambi* plantations also yield sweeter fruits in the drier tracts than in the more rainy places. In the Khandesh districts *Santra* oranges grow to excellence as the tract approaches the Central Provinces and the climate is nearer the one which prevails in that province, which produces the famous Nagpur oranges. Pummelo can stand a heavy annual rainfall and thrives in the Konkan tract. In fact, pummelo trees do not bear good fruits in the drier Deccan climate. The *kagdi limbu* trees also thrive well in the North Kanara district, where the annual rainfall goes above 120 inches, but they do not seem to dislike the dry climate, provided there is enough irrigation. Extensive *Kagdi limbu* plantations are seen thriving in the Poona, Nasik and Khandesh districts, where the rainfall does not exceed thirty inches annually.

Rainfall

It has been stated that the original home of some citrus varie-



JAMBURI FRUITS.

This is the chief root stock variety in Western India.

Facing page 143.

ties is the foot of the great Himalayan Mountains, from which it is evident that they can naturally grow up to a considerable height from the sea level. The average altitude of the Deccan plateau, at least of that part of it which falls in the Bombay Presidency, is not more than about 2,000 feet. These places are, therefore, very favourable for citrus trees. In this Presidency no damage is caused to them by low temperature, as frost generally does not form a feature of its eastern parts. The higher temperature of the eastern parts of the *Desh* (Deccan) tract is considered very helpful in producing quality fruits.

Altitude and temperature

In Ceylon, lemons are grown in semi-dry areas at 3,000 to 4,500 feet. Some South African lemons showed good progress in that country.

As stated above, the Presidency of Bombay grows only the *Santra*, the *Mosambi* (the Mozambique or sweet orange) and the lime on plantation scales. Besides these chief commercial varieties, there are in this Presidency, about twenty other varieties found scattered in different places as individual trees. The oranges of Bombay fall into two distinct groups, namely, the close-skinned or tight-jacket oranges, and the loose-skinned or loose-jacket oranges. Both were considered till lately by some people to belong to a single species. Their common botanical name was accepted to be *Citrus aurantium*. Bonavia (39) differentiated these two groups into *Citrus aurantium sinense*, Gallesio—close-skinned oranges, and *Citrus aurantium sinense*, Rumpjius—loose-skinned oranges. But the two groups differ widely in many points, and they rightly fall into two separate species. According to the scheme of Swingle, the close-skinned *Mosambi* group of oranges goes under *Citrus sinensis* Osbeck, and the loose-skinned *Santra* group or mandarin group goes under *Citrus nobilis lour*, which Swingle has now altered to *Citrus reticulata*, Blanco. There are further what may be called horticultural varieties in these species. *Citrus sinensis* Osbeck, includes the *Mosambi* orange, the Navel orange, Valencia and a large number of other varieties. The *Mosambi* is a distinct variety, and is at present of great economic importance in this Presidency.

Varieties and their classification: Oranges

The mandarin orange (*C. reticulata*) represents a group that

has no less than four different varieties grown in this Presidency. They are the *Santra*, the *Kavla*, the *Ladoo* and the *Reshmi Narangi*. The *Santra* is perhaps the best of the loose-skinned types of oranges. Tanaka (284) appreciates it as unequalled in quality and names it as *Citrus poonensis*, Hort. ex. Tanaka. Hodgson (122) thinks that the *Santra* is identical to the famous *Ponkan* of Southern China, which opinion is also shared by Milsum (176) who, therefore, designated it as *Citrus chrysocarpa* Lush. The other types are inferior to the *Santra* orange. They are also different from one another and may be considered as separate horticultural varieties.

Citron and lemon types

The citron, the lemons and the limes were all considered as only varieties of *Citrus medica* according to Linnaeus. Swingle isolated them into three separate species, *Citrus medica* Linn, (citron), *C. limonia* Osbeck (Lemon) but most recently—*C. limon*, Linn Osbeck, and *C. aurantifolia*, Swingle (limes). The lemons of Bombay present at least two and possibly three horticultural varieties of *Citrus limon*. They are *Jamburi*, *Id limbu* and perhaps also *Sakhar limbu*. The first two are sour (or rough) lemons, while the last named is sweet. The *Sakhar limbu* is also widely known as sweet lime and designated by a number of authorities as *Citrus aurantifolia*. Hodgson (122) considers that this fruit is of Indian origin and resembles the Persian lime from which it differs in its large size and different form. On these considerations, he believes that it comprises a good botanical species. Tanaka (296) has also formed the same opinion and has designated it as *Citrus limettiodies*, Tanaka. It seems safe to treat this as a hybrid, till taxonomic opinion entitles a definite opinion.

Limes

The limes fall into a distinct species, and are named *Citrus aurantifolia*, Swingle. These include such varieties of Bombay as the *kagdi limbu*, and also the *godhadi limbu*, and the *pat limbu* whose exact specific status is yet to be determined. The *godhadi limbu* has thicker skin than the *kagdi* (papery) *limbu*. The *pat limbu* is longish in shape, while the others are globose.

Much confusion in the classification of Citrus appears to be due to the lack of a standard horticultural system of classification as distinct from the systematist's idea of classification. The maze of species, varieties, strains and mixtures of cultivated citrus is ever on the increase, and unless a united effort is made

by the workers on citrus to adopt a universal system based upon a study of the genetics, bio-chemistry, physiology and karyology of the citrus race, the existing confusion is bound to continue. Kozhin (144) states that "A species should be, as is Linnean, genetically an aggregate unit, and the result of a whole system of elementary forms, which, continually crossing with one another keep within the limits of definite specific characters." If this is accepted, Tanaka's (273) attempt to give specific ranks to seedless varieties, which cannot even reproduce themselves true to type without man's interference is unsound.

The important citrus fruits grown commercially in the rest of India and Pakistan are the following:—

Other citrus fruits in India

The Punjab, North West India, Sind and Western U. P.:—

Malta and blood red oranges, (*Citrus sinensis* Osbeck); *Santra* (*C. nobilis*, Lour or *C. chrysocarpa* Lush or *C. reticulata*, Blanco); *Mitha* or sweet lime (*C. limetioides*, Tanaka or a hybrid), and a number of strains originated from chance seedlings not yet identified.

Lower foot of Himalayas:—Limes (*C. aurantifolia*) and a number of strains of lemons (*C. limonia* or *C. limon*).

Assam:—Strains of *C. nobilis* or *C. reticulata.*

Central Provinces, Western part of Orissa and Agency tract:—Santra mainly. Two strains, one with smooth skinned round fruit, and another with a slightly warty skinned fruit, drawn out towards the stylar end.

South India:—The mandarin is of considerable importance in Coorg agency tracts, lower Palni Hills, Yercaud and the Orange valley of the Nilgiris. Two varieties of sweet oranges (*C. sinensis*, Osbeck), namely, Batavian oranges and *Sathgudi* (Syn. *Satkudi* or Chinee) are grown in the northern or north-eastern parts of the Madras Presidency. *Mosambi* oranges are also grown on a small scale in the Kurnool district. Acid limes (*C. aurantifolia*) are grown on a very large scale in a

large number of districts particularly in Northern Circars, Ceded districts and parts of Madura and Tinnevelly. Pummelos are prominent on small orchard scale in the West Coast and Northern Circars. A variety of sour oranges known as *Vadlapudi* or Guntur sour oranges is of considerable commercial importance in Northern Circars, particularly in Guntur and Kistna. The Madras Presidency is also rich in a number of citrus varieties ostensibly having their origin as chance seedlings, one of which has been recently identified as *Citrus maderaspatana*, Tanaka, and is receiving attention now as a possible rootstock variety of value for cultivated forms of oranges and limes.

In India, citrus has produced a host of new types, as the various cultivated species have access to other conjugally compatible species. Chance seedlings have appeared and have produced a notable increase in varieties of all kinds of citrus species. In the regions of South India, where seedling plantations are still the rule, several citrus have originally appeared as chance seedlings just as the Satsuma orange had done in Japan. Hodgson (122) has stated that the very large number of peculiar and some very distinctive citrus fruits which occur in India form one of the interesting features of Indian citriculture. The multiplicity of these forms renders the task of classifying them botanically or horticulturally great and difficult.

Propagation

The chief commercial varieties of citrus, namely, the oranges, are propagated in Bombay Presidency by budding them on rough lemon (*jamburi* as it is locally called) rootstock. Other varieties like *Kagdi limbu*, pummelo and citron are grown as seedlings and no budding is yet being done commercially in their case. The method of budding adopted is the shield method, with no wood attached to the budshield, and it is the pride of several gardeners that the success they attain with this method is cent percent. *Kagdi limbu* is lately being budded on *jamburi* on a small scale and so are the new introductions, namely, the Navel Orange and the grapefruit.

Jamburi, or the rough lemon, is acknowledged as the best commercial rootstock variety for raising citrus types in Bombay Presidency. It is a very inferior and hardy variety of citrus and belongs to the lemon group. It has come into prominence in commerce in the Bombay Presidency and in fact all over India, only as a rootstock variety, which combines in itself all the desirable qualities of a good rootstock. It is never cultivated independently on a plantation scale. One or two or a few trees of this variety are generally seen in plantations of *Santra* or *Mosambi*. Their fruits are not used except for pickling purposes. Their seeds are the only products of economic significance at present.

Rootstock

Merits of *jamburi* as a rootstock

Jamburi as a rootstock is referred to by Paranjapye (193) in the following words: "The essential conditions required in a stock are that it must remain in sap flowing condition for a considerable time to facilitate the budding operation at any suitable time; that it must grow fast; that the bark when being loosened from the wood below must separate readily; that it should not tear irregularly; and that it must feel very watery to the finger inside. Such a stock is to be found in *jamburi*, which may be safely used for budding on." The position of *jamburi* as a rootstock in comparison with other kinds of rootstocks tried here is made clear by the same author (193) in the following words: "The bark of the *Mahalung* (Citron) stock is somewhat brittle and less mucilaginous and the sap flowing condition lasts only for a short time. The *Reshmi* orange is not at all suited as a stock, for the bark closely adheres to the wood below and it is not moist enough inside. This and the Nagpur orange stocks when cut off above, the wood often turns black near the cut end causing ultimate decay. With the pummelo (shaddock) as the stock, the great difficulty is that it does not stand well the trimming of its tap root and hence it is not well suited as stock plant, which must stand repeated transplantings. The *Mosambi* stock is very sensitive to cold, as in case of low temperatures the part of the bark of the stem that remains under water decays in a very short time. The *jamburi* stock is free from all these faults."

An experiment laid down in 1932 to find out if certain rootstocks could resist the die-back disease prevalent in Bombay

Province, showed the growth of *Mosambi* on *jamburi* to be better than the remaining rootstocks (217).

Jamburi is a popular rootstock in all parts of India and has also been found experimentally to be the best for Malta oranges in North West India by Brown (46).

The most important rootstock varieties in use in other parts of India and the world are listed below. They are discussed in detail by Hatton (114).

Other rootstocks

1. Sour or Seville orange (*C. aurantium* Linn):—According to McAlpin (168) among the four chief rootstocks used in Victorian citriculture, *viz.*, citronella or rough lemon, sweet orange, sour orange and trifoliate orange (*Poncirus trifoliata*), a disease affected 30% of the trees on sour orange rootstock, and appears to be similar to the "quick decline disease", of the U. S. A. or the "tristeza" disease of South America. Further plantings of citrus varieties on sour orange have been discontinued until a remedy for this disease is found. Similar reports have been published from other areas too, so that the sour orange is now in disfavour almost all over the globe.

Sour orange was once considered to be the most suitable stock for Southern Nigeria (211). Hume (129) stated that a large part of the world's commercial output of citrus was grown on this rootstock. It is said to possess an abundant and deep root system and is considered to be the best on heavy and wet soils. It is also said to be immune to foot-rot and all the gum diseases, but very susceptible to citrus scale and to quick decline disease. Trees on this rootstock are reported to be not very free bearing in the early stages, but the fruit quality is said to be better than on rough lemon.

2. Sweet orange (*C. sinensis* Osbeck):—This is very susceptible to *Mal de Goma* foot-root, and is unsafe to use except on light and dry soils. It has a shallow root system but produces shapely trees (189). Recently in California sweet orange rootstock is reported to be gaining popularity (232).

3. Trifoliate orange: (*Poncirus trifoliata*, Raf):—This is used as a rootstock in China and Japan. It does not do well under tropical conditions. Its value lies in its being the hardiest of all rootstocks and is therefore used in frosty localities. It has a dwarfing effect on the scion.

According to Benton (21), *P. trifoliata* is to be regarded as a valuable rootstock under a variety of conditions in New South Wales. Apart from its immunity to *Phytophthora* root-rot, it has ability to thrive in soils too moist for other rootstocks, has beneficial influence on flavour and fruit quality in general, induces early bearing and possesses a tendency to increase production.

4. SHADDOCK (*Citrus maxima* Merril or *C. grandis* Osbeck):—In Egypt it is supposed to be valuable as a rootstock on dry land. It is immune to foot root. In the Philippines it has been found that plants budded on Shaddock are liable to be badly affected by mottle leaf (152).

5. GRAPEFRUIT (*C. paradisi* Macf):—The root systems of pummelo and grapefruit are reported to be more fibrous than that of either sour or sweet orange, but these have a small and crooked tap root. The lateral spread of roots is enormous. It is somewhat susceptible to foot-rot, and certain kinds of gummosis. On the whole, accounts vary about its success in other parts of the world.

6. ACID LIME (*C. aurantifolia*, Swingle):—The plants of this species are rather difficult to work upon. According to Brown (47), it is a suitable rootstock for scions of its own variety. It is not used on any large scale for other scion varieties. Very recently it has shown encouraging performance when used as a rootstock for sweet orange and lime at Kodur.

7. SWEET LIME (*C. aurantifolia*, var Swingle, syn. *C. limmettioides*, Tanaka or a hybrid):—In North-West India, this is used fairly extensively as a rootstock for Malta oranges and *Santra*. In the rootstock trials in North-West India (47) it was found that the sweet lime is not a suitable rootstock for Malta oranges but perhaps the best for *Santra*. It is easily raised from cuttings, and is being used as such in the rootstock trials in some research stations in India. With rough lemon, this forms one of the two most important rootstocks for *Santras* in the Central Provinces (136).

8. CITRON (*C. Medica. L.*):—A variety known as *Mokri*, is largely used in some nurseries in the United Provinces and the Punjab. It is also in use on a small scale in Egypt. It is very easy to work upon and produces very quick growth in the initial stages. But because of its reported susceptibility to diseases and

its short orchard life, this rootstock is held very much in discount.

9. Mandarin orange (*C. nobilis*, var. *deliciosa*, Swingle or *C. reticulata*, Blanco):—This is used in China and a variety of this (Cleopatra) is also found suitable in well drained sandy soils of Florida. It is said to be immune to scale and resistant to gummosis. Tangerine is used as a rootstock for its own scion in South Africa.

Some experimental work is being done on the indigenous citrus rootstocks of Assam at the Government Citrus Fruit Research Station, Bernihat. The relative merits of *Rabab Tenga* (*C. grandis*), *Soh Myndong* (*C. jamburi*), *Pani Jamir* (*C. limon*), *Karun Jamir* (*C. curantium*), *Sat Kora* (*C. macroptera*) stocks are under investigation. The scion used is Khasi orange (*C. reticulata*). *Soh Myndong* is important for imparting maximum growth to the scion. *Rabab Tanga* has recorded the maximum stock girth. *Pani Jamir* rootstock, which is somewhat sweet and insipid has produced very sour fruit with Khasi orange scion.

There are a number of other varieties in limited use in various countries. *Citrus sunki*, Hort. is of some importance as a rootstock in Japan. In the Madras Presidency, a number of varieties that have originated as chance seedlings and appear to have potentialities as rootstocks have been recently propagated and are being tested for their suitability to sweet orange and acid lime scion varieties. In the Punjab and Central Provinces also, rootstocks of different varieties are being examined for their value to Malta orange and *Santra* respectively. The work of discovering the right type of rootstock for the cultivated citrus varieties grown under diverse climatic and soil conditions in India is highly important, and in this work the possibilities of indigenous citrus varieties require to be tested along with the well-known varieties in use in other countries.

The citrus rootstock experiment carried out at Montgomery (Punjab) showed that *Kharna Khatta* was useful for all citrus varieties there except in the case of Blood Malta, for which rough lemon was found to be the best stock. *Jullundri Khatti* was a mediocre rootstock for the local Malta and was not associated with vigorous growing trees with heaviest yields of excellent quality fruit (217). What these rootstock varieties are exactly, is yet to be determined by proper taxonomic studies.

Halma (106) reports that Eureka lemons on their own roots, after 16 years proved to be less vigorous, less hardy and less productive than vegetative progeny of the same parents budded on grapefruit and sweet orange rootstocks.

Hodgson and Cameron (123) report that in citrus trees it has been established that the scion determines the rate of growth and ultimate size of the tree when its vigour is less than that of the rootstock.

There is evidence to show that certain strains of a species apparently produced better results than other strains of the same species. If this is true, it represents a more extended problem of rootstock influence, and, therefore, has to be taken into account in our future rootstock trials.

In a rootstock trial in Bombay, it was found that seedlings of different strains of *jamburi* varied considerably in their general performance and vigour of growth under strictly uniform conditions (56).

In Queensland, seedlings of sweet orange and rough lemon were popular as rootstocks, while sour orange is less common possibly because of its slow growth (202).

In California, the tendency in 1936 was towards the suppression of the sour by the sweet oranges as the principal rootstock variety for the oranges. Rough lemon was rarely used (165).

Different soils react upon the rootstock to produce in some cases very vigorous trees and in others short-lived and weak individuals. The grower has also to understand that the problem of orchard culture does not merely rest in terms of the quality of water or manure applied, but also in the optimum use made of the moisture and soil nutrients by the roots. The importance of root system lies not only in its anchoring the tree, but also in its power of absorption of moisture and soil nutrients. A deep and extensive root system is helpful in giving the desired mechanical support, and in retarding the desiccating effect in the soil. This fact becomes progressively important as the moisture content and fertility of the soil diminish. An extensive root system is inhibited under constant wet soil conditions, but is encouraged under conditions of good aeration and moderate water contents. The root system of some varieties is much more extensive than that of others. Soil texture and structure also affect the depth and spread of roots to a con-

siderable extent. It is, therefore, most necessary to select a rootstock variety that will produce the best of root systems on a given site and can promote the best of growth and production within the available soil and water facilities.

Kharna Khatta irrespective of scion varieties is associated with most vigorous trees. *Jatti Khatti* gives vigour to its scion to a lesser extent. Mitha or sweet lime (*C. aurantifolia*) is a dwarfing stock (150).

The foundation of the citrus nursery industry in the Bombay Presidency is built on *jamburi* seedlings, which form the stock for all the superior varieties of citrus. *Jamburi* seedlings are raised from fruits which are ripe on the tree. The *Sakhar limbu* rootstock is also raised in some places for budding purpose.

Types of *jamburi*

There are a large number of types of citrus which go under the name of *jamburi* or *jambiri* or *jamberi* in different localities of India. These types differ considerably in shape, size and appearance of the fruit. What is generally known as *jamburi* in the Bombay Presidency does not also seem to be a uniform type all over the tract. The collection of citrus varieties at the Modibag, College of Agriculture, Poona, consisted of several types which were all named as types of *jamburi*. Each tree bore fruits that were in some way or other different from those of its neighbours. The characters of fruit alone give, therefore, no indication to the type of *jamburi*. The type of *jamburi* commonly used for stock in this Presidency has deep yellow colour, has a mammillate shape and the fruit is nearly round with a diameter of about three inches. The rind is wrinkled and somewhat loose. The pulp is exceedingly acid.

Fruiting seasons of *jamburi*

Jamburi trees bear almost all the year round in peninsular India. The three important seasons, namely, the December-January flowering, the June-July flowering and the October flowering all produce some blossoms at least on the trees. *Jamburi* fruits are therefore, available almost at any time of the year, although the chief season is July-August. In north and south India, *jamburi* fruits are chiefly available from October to January.

For the purpose of extraction of seeds, sound, healthy and tree-ripe fruits should be selected. Such fruits are allowed to

Extraction of seeds

rot, or are cut fresh and their seeds extracted. The seeds that float on water are useless for raising seedlings, and they should be rejected. Only the heavier seeds, which sink in water should be collected and used.

Seeds are then spread on ordinary blotting paper or on the floor under shade for drying for a day or two. Then they can be stored in a tin or glass jar till required for sowing. Mixing with ordinary wood ash before storing is desirable. *Jamburi* seeds have to be protected from rats and insects, while drying as well as while in store. The *jamburi* fruits contain about 25 seeds each. These seeds can well be graded into heavy and light seeds, and the former are experimentally proved to give more vigorous seedlings which become ready to receive the buds much earlier than the seedlings raised from lighter seeds.

Storing of seeds

Seeds of *jamburi* are polyembryonic as those of most other citrus. From one to eight embryos (or perhaps more) are seen packed together in a single seed. Each embryo has generally two cotyledons which are very irregular in shape except when the seed contains only one embryo. In polyembryonic seeds, one of the cotyledons is the largest of all, while one or two more may approach it in size. The rest are very thin and small, and may be reduced to almost translucent scales, especially when they are placed in the interior of the seed. When the seeds are sown, some of the more vigorous embryos are seen to develop into seedlings. It is for this reason that more than one seedling are seen to spring up at a place where only one seed is sown. The number of seedlings arising from a single seed may be four or more in number. More than half the number of seeds, give rise to two or more seedlings. The vigour of all seedlings arising from a single seed is not the same. In fact, it varies remarkably. One of the seedlings is the most vigorous of all. Others follow in regular gradation. The difference between the best and the second best seedlings is considerable, going as high as about 50 percent. Seedlings that come next in order are really too weak to be considered. Reviewing the literature (114) on polyembryony it is stated that the presence of more than one embryo within the seed may be ascribed to a stimulus received by the cells of the nucellus

Polyembryony in seeds

both above and below the embryo-sac, even though separated from it by several cells. As neither spore nor egg-cell is involved in this reproduction process "the formation of these additional embryos may in effect be regarded as a case of adventitious budding, analogous in its results to true vegetative reproduction". Only one seedling is a true cross, while others which may number as many as ten, will in no way differ from the mother plant. Toxopeus (305) shows that the generative offsprings, as distinct from the vegetative seedlings, of Japanese citron and rough lemon, amount to only a small percent in the latter and may be fifty to sixty percent in the former, and show very poor growth and are, therefore, easily distinguishable. If the weakest seedlings are removed, it will result in the retention of the seedlings that would show less genetic variation. Webber (323, 331) has confirmed the value of this type of selection in citrus nursery practices, but proceeds to point out the necessity for selection of large sized seedlings in the nursery even among the apogamic or nucellar seedlings.

In the nursery it will be, therefore, profitable to remove in the very early stages all the multiple seedlings, leaving only the best and the second best. This will do away with a good deal of congestion for the seedlings, and will save the remainder from unnecessary competition in regard to space and plant food. It will also eliminate very considerably variations in the seedlings which are further on to serve as rootstock plants, by getting rid of all the generative seedlings which are the weaker ones as noted above.

Seeds with split coats

A number of *jamburi* seeds are found to have their seed coats split even while they are inside the fruit. The split seeds do not seem to differ from sound ones in their general characters. They look healthy and normal in all other respects. They are, moreover, mostly of the larger seeds and amount to about twelve percent of the total number of seeds in the fruits. The splitting or opening of the seed coat is one of the various changes a germinating seed undergoes. It seems that these split seeds have already started on their course of germination. This shows that the seeds have a natural tendency to prepare themselves for germination immediately after their development is complete. If

left long enough, the split seeds germinate inside the fruit itself as it often happens in overripe fruits.

Heavy seeds of *jamburi* are graded out and sown in raised seed beds. Such seed beds have the advantage of permitting better drainage of the soil. The land is first of all dug well to a depth of about six inches. All the clods are broken and manure is added to the land at the rate of about twenty pounds per running yard of the bed. Seed beds are ordinarily three feet broad and ten to twelve feet long. If the soil is clayey, a basket (30 pounds) of fine sand may be added to every running yard of the bed. The whole lot is then well mixed and worked into the ground soil and levelled. This usually raises the bed area about six inches above the general ground level. In the raised bed, seeds are sown in straight lines across the bed at a distance of about six inches apart, and covered with about an inch of the soil and pressed well. Copious watering is done immediately after sowing. Water is then given daily once to sufficiently wet the bed.

Sowing of seeds

Reichart and Perlberger (216) working on the diseases of citrus in the nursery beds, recommend that the best nursery soils for citrus beds should have a sufficient supply of plant food and a high water percolating capacity. A soil containing four parts of sandy clay with one part of old crumble manure of more than two years old is the best. If fresh manure or organic matter as dry leaves or straw is added, it favours the spread of disease. The soil surface of the seed bed should be at least ten centimeters higher than the surface outside, and the beds should be covered with at least two centimeters layer of sand or gravel, and the seeds should be sown four to five centimeters apart. Excessive humidity is caused by closer sowing. Watering should be frugal but frequent, and only the upper layer should be kept moist till germination occurs. Three to four weeks after sowing, the upper layer should be kept as dry as possible and the lower layer moist. Collar of the plant should in no circumstances be kept moist.

Observations made on germination of *jamburi* seeds have shown that they are very active in germinating when quite fresh. Their activity declines rapidly after extraction from the fruits. It comes down to a certain degree in about nine days and this degree of activity is maintained for a long time. The length of germination period

Germination of seeds

varies vastly. It may extend from 22 days to about 80 days. In general, this period appears to be comparatively long in the case of fresh seeds, that is, when the seeds have been in store for not more than about a fortnight. Seeds sown after keeping for long periods in store have a much shorter period of germination. *Jamburi* seeds can be preserved without materially losing their viability for about four months. If sowing is delayed for about a week or more, the seeds start germinating a little later than when they are sown fresh. This delay which may be about a fortnight need not lead nurserymen to think that the seeds have lost their viability and will not germinate. Hume (129) also records that citrus seeds do keep for "several months" without losing their viability.

Nursery beds

Germination is seen first about three weeks after sowing is done. Until then, no disturbance should be caused to the surface of the bed or else some germinating seeds may be damaged. Germination may last for over two months and until then care should be exercised in removing the weeds from the beds. When seedlings have grown for about a month, all weeds may be removed and the interspace between the row of sowing may be lightly stirred with a weeding hook (*khurpi*). When the seedlings are about two months old, it is time to thin out some of the weaker ones, and to clip off the multiple seedlings arising from the same point so as to relieve congestion, and to afford space for the proper growth of the remaining seedlings. At the same time, the seedlings should be daily examined for caterpillars of lemon butterfly which look like dirty droppings of birds in the initial stage and which eat the young leaves and shoots of the seedlings. These tiny insects should be hand-picked and killed. If this care is not taken, the seedlings will all be seriously damaged. When the seedlings grow up, this trouble is not so seriously felt. The caterpillars are more common in the rainy season. When the seedlings are about three to four months old in the seed-bed, they are removed carefully and transplanted in flat beds or on the side of ridges and furrows specially prepared for them. The ridges are about two feet apart and seedlings are transplanted on one side of the ridge about a foot or less apart. In flat beds, transplanting is done in double rows about a foot apart, and separated by two feet distance from the adjoining double rows.

Each bed has four rows of seedlings in all and the seedlings are transplanted singly. These beds are called nursery beds and close planting in them is favoured, as by close planting seedlings generally grow erect and form few lateral shoots. A straight and erect stem is essential for budding upon.

Care of nursery beds

Nursery beds are watered immediately after transplanting, and again after four days, and then regularly at intervals of eight to ten days. Weeding and stirring the soil are of importance as the vigorous growth of the seedling depends on these operations, as much as upon occasional manuring, consisting of light doses of sulphate of ammonia or cattle urine. Manures are usually given just before or after irrigation turns. The soil is also stirred at least once in a month.

In order to develop good rootstocks, the side shoots produced by the seedlings are nipped off every now and then; the earlier they are so treated the better, as they leave no mark on the main stem. If they are clipped when branches have formed wood, the main stem becomes knotty, and unsuited for budding. With this treatment, seedlings become ready to receive bud in about a year from transplanting in nursery beds. If large seeds are selected for sowing and then if vigorous seedlings alone are sorted out for transplanting, they may become ready for budding in about a year from sowing the seeds.

Grading of seedlings

Roguing out the variants or undersized plants from citrus seedlings in the nursery beds is shown by Webber (331) to be very important for obtaining only vigorous and uniformly growing seedling rootstocks of apogamic or nucellar origin. Observations collected at Poona on the graded seedlings have shown that:—

1. The first class seedlings show better growth than the second class seedlings even when they are young. They make a more rapid growth when they once get a start, and establish remarkably their superiority over second class seedlings.
2. The poorer second class seedlings develop side branches at a much earlier stage than the more vigorous first class seedlings.
3. At the age of four months, the first and the second class seedlings attained a girth of 1·44 cm. and 1·29 cm. and at eleven months these girths were

2·90 cm. and 2·0 cm. respectively. At this age the first class seedlings were fit to receive the bud while the second class ones were not.

It is convenient to bud the rootstocks at a height of about six to eight inches (15 to 20 cm.) from the ground. The rootstock plants should, therefore, be straight and without branches upto a height of about 25 cm. at least to facilitate the budding operation. Branching below this height greatly diminishes the thickness and vigour of the main shoot of the rootstock plant. Nurserymen accomplish these by two methods:—

1. Small seedlings are transplanted in beds as close to one another as possible, only leaving enough space, just to do the budding operation conveniently. Close planting in this way naturally discourages the branching on the sides of the seedlings.
2. As an additional precaution, they remove by hand all the side branches that might arise on the lower 25 cm. of the rootstock by nipping them in the bud. A clear rootstock stem is thus obtained.

It is evident from this that first class seedlings have a natural tendency to grow without branching in their earlier stage, and provide the best rootstock from the nurserymen's point of view. They may not require any special attention to secure a clear stem of about 25 cm. in height. Another point the first class seedlings have in their favour is that they grow very vigorously when they once get a start. This is important from the point of view of the planter. Rootstock plants must also be healthy, strong and vigorously growing. Buds inserted on vigorous rootstocks grow very fast and give the best plants. As the rootstock forms the foundation of the future tree, it is essential that only the best rootstock plants are always selected for use.

For the actual budding operation, it is necessary that the rootstock plants should be in sap flowing condition in order that the bark may split easily and that the buds may "take" quickly. But it is also necessary that the rootstocks attain a minimum stage of maturity, when they can be budded upon. This minimum stage of maturity is reached by the first class seedling much earlier than by the second class seedlings. High budding has been recommended by some as a preventive measure against the attack

of gummosis. This disease is generally seen to start from the bud-joint and spread upwards. It is encouraged by wet conditions of soil. If the stem and particularly the bud-joint is kept free from contact with the soil or irrigation water, it is suggested that the incidence of attack will be minimised. The bud-joint can be kept away from the soil or water by budding the rootstock plants sufficiently high. Budding at a height of at least 18 inches is recommended. If this has to be achieved, it is necessary that only very vigorous seedlings should be selected as rootstocks, because in some cases weaker ones do not take buds sufficiently high. First class seedlings are, therefore, to be favoured from this point of view also.

Budding

When stock seedlings are about a year old after transplanting from the seedbed, they are budded upon with buds of *Santra*, *Mosambi* or other superior types of citrus. The method of budding commonly adopted in the Bombay Presidency is the shield method. It consists of giving a 'T' or an inverted 'T' cut in the bark of the rootstock plant in a suitable place about eight to nine inches from the ground or where the bud is to be inserted. The bud from the scion stick is carefully removed by cutting it off the budstick along with a slice of bark. This is then inserted carefully inside the bark of the rootstock with the growing point of the bud upwards, and tied with a strip of fine banana fibre. While thus bandaging, the growing point is kept open in order to allow it to sprout and grow. The bud should be preferably inserted on the northern side of the rootstock to prevent direct rays of the sun falling on it and drying it up after insertion. As an additional precaution a leaf of the rootstock may be removed and tied over the bandaged portion to shade the bud for some time after budding. When the cut on the rootstock is straight, it is usually necessary to bend the rootstock stem slightly towards the operator, so as to make the bark open out naturally and permit the insertion of the bud. In this case the bark of the rootstock holds the inserted bud tightly when it is released back to its natural erect position, and contact of the uniting surfaces is facilitated.

Contrary to the prevailing practice in some parts of India, it is found that in many parts of the world the practice is to use bud-shield with a piece of wood attached to it. This practice has also been found at Kodur (Madras) to produce a greater success

in budding and to promote a better growth of bud sprouts. The budders are also able to turn out more work per day. This system, however, has not gained popularity as yet in commercial nurseries in some parts of this country. In South India, paraffin cloth is used in preference to banana fibre as a tying material around the budded region.

Selection of buds

Just as it is essential that the rootstock should be in sap flowing condition for success, it is also necessary that the buds in proper condition are selected for the purpose. Young shoots of citrus are generally tender and angular. Growths which are one or two seasons old are more mature and rounded. Small discontinuous streaks of greyish colour also appear on them. Such branches should be selected as sources of buds for propagation. The trees from which bud-sticks or bud-woods are taken should be in a growing state, so that the buds are in a sap flowing condition and they can be easily removed from them. This condition is noticed by pinching a thin piece of the bark and drawing it off the wood. If the bark peels off easily and if the exposed wood is mucilaginous one may be sure of the proper condition of the branch selected. This test holds good for rootstock plants also, for finding their suitability to receive the buds.

Budsticks are generally about six inches long and have three or more *unsprouted but well developed* buds on them. Sprouted buds and buds with thorns are unsuitable as they cannot produce any success, because while separating they almost always damage the germ or the growing point. If, however, a piece of wood is retained in the bud-shield, it is possible to use the buds containing thorns also.

As pointed elsewhere, bud-wood should be cut only from the best and heavy bearing trees of the most valuable strains that are known to bear fruits of the right quality. That a large number of trees even in the best of citrus groves are unprofitable, and planting of cent percent inherently heavy-yielding or profitable trees furnishes the best means of increasing the orchard income are facts that have long been realised by citrus growers in other countries. Hodgson (120) has shown that even in the most profitable orchards in California, approximately one tree in three is either only self-supporting or is actually grown at a loss. In the average orchard, the non-profitable trees amount to about fifty

percent. Webber (326) has pointed out that in South Africa, some groves are planted to trees almost quite worthless as commercial sorts, and many trees are inherently low-yielders year after year. In an experimental plantation raised with great care and after repeated selection of individuals, Batchelor and others (14) have shown that inherent qualities of the tree is one of the most important causes for variation in tree yields. Further evidence of the variations in trees caused among others by the variations inherent in the buds due to heritage has been advanced by Webber in 1920 (337). These facts make it essential to carefully select the parent trees as sources of bud-wood.

It is best to use bud-sticks as soon as possible after they are cut. If it is necessary to retain them for some time; they should be wrapped in moist sphagnum moss and stored in a metal case with closed lid in a cool place.

As a result of seed variation and changes appearing in the somatic tissues of the plant, mutations or sports occur in citrus plants. Forms due to change of somatic tissue are known as "bud variation." In plants, improvements can be accelerated by careful observation and isolation of desirable bud mutations. Conversely, the elimination of inferior bud mutations are of considerable importance in propagation of trees from a fruit like some varieties of citrus which are especially subject to mutations. By such careful selection of mutations and scion parents qualitative inheritance is assured, undesirable kinds are eliminated, the product is standardized and new strains are easily picked up.

Bud variation and mutation

The Washington Navel is a variety which is liable to bud variation. Shamel and Pomeroy (237) in the United States Department of Agriculture, who made careful investigations, have shown by yield records that each variety in addition to its being stable and constant in yield, is composed of several strains which are capable of perpetuation through vegetative propagation. From individual records, they found that high-yielders were always maintaining their hereditary nature of productivity and that qualitative characters such as shape, taste and seedlessness are transmissible.

Some workers may not admit Shamel's accepted theory that the ribbed, corrugated, seamed or otherwise abnormal characters noted on certain lemons and reproduced in progeny by

asexual propagation are bud-sports. According to some authors the tumor in Washington Navel considered by Shamel as bud mutation is nothing but a disease of some sort of virus. This can be transmitted by vegetative propagation.

In citrus fruits, Shamel and Pomeroy have listed 187 bud mutations in Washington Navel orange alone and 51 in Valencia orange (237). Webber (320) points out that Shamel's method and principles of bud selection have been criticised by some investigators under the erroneous assumption that those principles and methods were based on the supposed continuous improvement made by selecting generation after generation from high yielding trees. The main factor achieved by bud selection, which is now being done almost in every country is the greater certainty that the trees produced from good selected mother types will be more uniformly of the standard good type and more productive. An instance of successful commercial introduction of a strain in Japan through the propagation of bud mutation has been pointed out by Tanaka (277). Caryl (52) has pointed out that by means of bud selection, thorns have been eliminated, late and early types have been separated, minor varieties removed and quality improved.

Shamel's work has now received very wide recognition and numerous new strains propagated from a single bud taken either from a limb or an entire tree variation are being extensively popularised in most of the citrus growing countries. Since 1916, very few orchards have been planted, which have not been propagated from selected buds from inherently productive parent trees in California. Probably ten million buds have been sold to California growers alone as a result of Shamel's work. Two special strains produced recently—the Robertson Navel Orange and the Don grapefruit—are now being widely distributed, and seem to have great promise. In addition to these benefits to the industry, Shamel's work has been of great value in teaching growers to keep a close watch for branches mutating towards poor types so that they can be eliminated from the orchard. Shamel's work has emphasised the importance of propagating only superior individual trees of outstanding merit based on the yield records and other observations of at least four or five years. Freedom from and resistance to disease should be made a primary consideration in such work. Great care should

also be taken to avoid propagation of limbs producing inferior bud-sports. Unintentional propagation of undesirable strains is bound to bring about a progressive deterioration in citrus orchards and it is, therefore, the duty of growers and nurserymen to not only preserve the best trees and look for more valuable ones, but also to prevent the multiplication of progeny from inferior bud mutations. Frost (91) believes that bud variation forms of citrus presumably originate in single cells, either by gene mutation or by differential mitosis. Variations also occur even among the apogamic seedlings, and this is considered to be due to chimerical conditions in the parent trees.

In the Presidency of Bombay, bud mutations have not been extensively isolated. But several clonal strains which seem to have originated by this process do exist in the cultivated local types of citrus. Examples of such clones are provided by the thick-skinned and thin-skinned *Mosambi* oranges. The round and oval types of limes, the *jamburi* and *id limbu* strains of lemons, etc., are believed to have originated as chance seedlings, as in the case of these fruits, vegetative propagation is rarely resorted to. A type of variegated lime has been isolated some time ago from a mutant branch of an ordinary lime tree. This branch had its leaves and even part of its stem variegated with yellowish and green patches all over. It was propagated by marcotte, and the progeny have retained the variegation. The new clone, however, is not of much economic value, as it is a shy bearer. In Madras one pinkfleshed Vadlapudi orange mutant has been detected and perpetuated recently.

Time for budding

Budding can be done with success at any time of the year in Bombay Presidency, when the plant is in growth. This generally happens when the cold season passes into spring and when the hot months are followed by rains. Buds inserted at other times take a very long time to sprout. Budding during rains is not advisable because the rain water might get into the wound caused in the rootstock during the budding operation and ultimately cause the tissues to rot. In that case no union of the bud is possible. It is considered desirable to have at least a week of clear weather after budding is done. In North India, the optimum period of budding for citrus trees is either February to March or August-September. At Kodur (Madras) it has been found that July to

end of December provides the best budding season. Buds inserted after January immediately preceding the hot weather failed to produce good growth. The seedling rootstocks may be brought into condition to receive buds in about a fortnight, if so desired. The soil in the beds may be dug lightly and manured with farm yard manure and further given a light sprinkling of sulphate of ammonia. Irrigation should follow immediately. These treatments stimulate the plants to grow and come into flush within about a fortnight or three weeks. They can then be budded.

From the time of budding, the buds swell and sprout into shoots in about a month. If the buds remain green for a fortnight it may be taken that they are uniting. After a month the stock is headed off about 2″ above the joint so as to concentrate the sap on the scion bud. Sprouts coming up from below the scion bud are all nipped in the bud or rubbed off lest they make the scion bud starve. It is common among some Indian nurserymen to lop the rootstocks at the time of the budding operation itself. This, however, has been experimentally shown at Kodur (Madras) to result in a poor 'take' of buds and poor growth of bud-sprouts. In certain cases, it is seen that it is advisable to leave some nurse branches on the rootstock above the bud-joint until the bud sprouts and the sprout becomes strong enough to maintain itself, after which the nurse branch is lopped off. When the scion bud sprouts into a branch and grows to about a foot in length, the portion of the stock above the bud-joint is trimmed and cut close to the scion. The new sprout is then helped to grow erect by carefully tying it loosely to a stick or other support planted near the plant.

Lopping the rootstock

Nurserymen transplant budded plants when they grow well in the nursery beds. At Shikrapur, near Poona, where citrus plants are being raised commercially on a very large scale, transplanting of budded plants is invariably done in order to keep the growth of the tap root under control. If this is not done, the plants send their roots deep into the soil, and considerable difficulty is experienced in lifting them up for sale. The plants are transplanted in beds in specially selected shallow soils with *murum* below. In parts of the United Provinces and in the Punjab, transplanting

Transplanting

of budded plants is done several times to harden the root system, and to restrict the size of the roots to the narrowest limits possible. This naturally results in a considerable reduction in the weight of the plants and consequent reduction in the amount paid as railway freight and haulage charges. Often the tap root is twisted and tied into a knot to meet the same end. The knot gets fused together in course of time and remains unnoticed when the plants are sold, as the roots always remain covered with a ball of earth. When the plants are planted in their permanent place in the plantation without disturbing the ball of earth, the knots continue to remain intact. In course of time, the knot hinders the proper and normal growth of the root of the tree, and this may consequently accentuate die-back or other physiological troubles. The practice of knotting the root, is, therefore, considered harmful and should be given up. Leading nurserymen are now realising the evil effects of this practice, and adopting more efficacious methods to serve the same end. According to these new methods, the tap roots are cleanly and sharply cut at the required depth while transplanting. This helps them to develop lateral roots which do not go deep but mostly spread out in the upper soil layers of the bed. The roots develop callus and the wound heals up well if the cut is neat. It is noticed that this practice is not as injurious as that of knotting of the roots, although definite experiments on the comparative merits of knotting the root as against pruning it are not yet carried out.

Nature of buds and their growth

In the nursery as well as in the plantations, attempt should be made for obtaining a strong clean-stemmed plant of citrus, whether of *Santra* or *Mosambi* or any other type, by clipping off in the very beginning all the multiple branches, which might come up from the bud-joint or close to it. The buds of the *Santra* and *Mosambi* plants are almost invariably multiple, and as such, they give rise to more than one sprout. If the unsprouted buds of healthy branches of these trees are examined, it is seen that in almost all cases, two or more rudimentary buds are present in each axil of the leaf. They are not all of the same size. A transverse cut through any of them shows under a hand lens as many concentric circles as there are buds. Usually one of these buds is bigger than the others. Normally, the biggest and most

vigorous bud alone seems to give rise to a sprout. Occasionally two or more sprouts may be seen to come forth from a single leaf axil.

In the case of a single bud-insertion on a vigorous rootstock, the inserted bud-shield naturally gets more plant food than it would on the original mother tree. Not infrequently, therefore, such a bud-shield sends forth more than one sprout. To begin with, only one sprout may appear but later on when the rootstock is headed off, more sprouts are seen to arise from the base of the first sprout. This may be due to the extra food and stimulus the other buds get. A count was taken of the sprouts that came out of the original bud-shield in the case of fifty budded *Santra* plants, about one year after budding. It was seen from this count, that in many cases, the numerous sprouts that shot out gave a crowded and bushy appearance, with even eight sprouts springing from a single bud-shield in some instances. One or two of these sprouts are usually strong and vigorous, the rest being weak and angular. These sprouts may appear one after another, and their appearance may be expected at any time in a young plant. The buyer of budded plants is led to believe that the larger number of sprouts indicates the superior quality of the budded plant. The nurserymen, therefore, make no attempt to allow only one sprout to grow from the bud. A clean stemmed tree is obtained only from a plant which has a single sprout growing from the bud. A clean stem is desirable for the following reasons:—

1. A clean stem at the bud-joint makes the joint strong and the tree becomes straight and shapely.
2. The bud-joint is most susceptible to gummosis and the clean stem facilitates treatment against this disease by avoiding many inconvenient angles.
3. The stem borer is seen to attack grown up trees at the angles of the main branches, when they arise from the bud-joint. A single clean stem gives them least opportunity and facilitates treatment when there is an attack.
4. By allowing more than one sprout to grow from the bud-joint, the growth of the main stem is checked and the plant becomes bushy, with many a weak branch.

5. A straight clean stem up to about three feet high makes cultural operations easy, and increases conditions of hygiene in the plantation. This is particularly so in the case of *Mosambi* and grapefruit trees, which have a tendency to give out low-spreading branches. The shock which the trees receive by cutting off a large number of their branches at one and the same time would be avoided by proper care in training the plants as required from the beginning.

At the time of lifting the plants from the nursery, care should be taken to injure the roots as little as possible. It is usual to dig out the plants with a ball of earth around the roots. The size of ball varies at different places, but usually has a maximum diameter of one foot. If the plants had been transplanted a number of times, or if the period of lifting synchronises with the dormant period, the ball of earth is reduced to the minimum size. It is observed that plants imported from South Africa, Australia and America during the winter months arrive with little or no soil around the roots, but in a greater part of this country subject to mild winter conditions, it will be risky to resort to this practice. It is only in Coorg and Wynad that mandarin plants are sometimes lifted and sold with naked roots. Practical defoliation sometimes accompanied by pruning of a few of the shoots, is done at the time of lifting in order to reduce the transpiration of water through the leaves. Complete defoliation is done by South African and American nurserymen when sending plants to this country.

Lifting of plants

Training of the trees in order to have a strong frame-work is a point that requires attention at the time of tree-lifting. A modified leader system is considered to be the best for all citrus trees. According to this, only one leader or main shoot is allowed to grow, and all other shoots emerging from other leaf axils are considered subordinate to the leader. The secondary shoots should be placed in a spiral way around the leader shoot at suitable intervals. Violent pruning produces a large number of weak shoots or some tall and fast growing "sucker" shoots of not much value for the tree. Severe pruning of healthy and vigorous growing trees during the early years also tends to prolong the period

Training

of vegetative growth and delays the bearing period and should, therefore, be avoided. In order to secure symmetry and promote a strong frame-work, three or four secondary shoots, may be selected, which should be distributed as evenly as possible around the stem. If a shoot emerges immediately above or opposite another, one of the two may be removed. Similarly, crossing shoots are to be avoided. As pointed out above, two or more strong shoots should not be permitted to grow from one place very close to each other, as this will result in the formation of weak crotches. Long and vigorous "sucker" shoots should also be removed. Periodic inspection of the plot will be necessary to see that fresh growth does not occur from unwanted places consequent to the pruning done at the time of lifting.

Some authors recommend heading the young trees back in the nursery to twenty-eight inches to thirty inches above the bud-union. Three to five branches are suggested to be retained spirally around the trunk. If these are allowed to grow upright and the main limb allowed to grow uninterruptedly, it would produce a strong frame-work. The unpruned trees, however, made better growth and became better trees from all stand-points. The subsequent performance of the former set of trees showed that early fruiting of the unpruned trees has had no apparent detrimental influence on the growth or behaviour of the trees.

Vegetative propagation of rootstock

Propagation of all citrus to be used as rootstock by seed is an almost universally accepted method. It is easy and renders the raising of a much greater number of vegetative progeny through the selection of apogamic seedlings than would be possible by any other means, without spoiling the mother tree. Further, new varieties can be imported through seed, thus minimising the risk of importing diseases. Rooting of cuttings of many varieties of citrus is also difficult. Halma (104) after an extensive trial admits that sweet orange and grapefruit cuttings root less readily than the lemon, but points out that by a suitable method they can be made to produce a satisfactory percentage of rooted plants. On another occasion, Halma (104) has stated that success in rooting citrus cuttings is achieved by taking cuttings from mature or semi-mature wood, and

applying bottom heat and maintaining a high atmospheric humidity. In West Indies, some success has been obtained in raising rooted citrus cuttings in a solar frame, wherein the sun's rays are utilised to furnish heat to the beds (130). A few varieties of citrus have been propagated by cuttings at Lyallpur, while some nurserymen in Madras usually raise orange plants by gooty and some lemons by cuttings. Since the root system of cuttings is shallow at least during the early years (114), and the propagation by this and gooty methods involves the removal of more material from the parent, and also because of the possibility of certain diseases being transferred to the progeny from the parent trees, these methods, if used to raise root-stocks, are not only uneconomic but may in fact be inadvisable.

Other vegetative methods of propagation have also been tried with varying degrees of success in different parts of the world. Webber (335) reports that layered trees were as productive and vigorous as compared to budded or seedling trees. Enarching has also been practised to provide a new root system to old citrus trees that have damaged roots by planting one or more seedlings near the collar and inserting the wedged ends of these stocks to the base of the scion trees. Ringing of hard-wood cuttings of some citrus trees for the production of roots was also shown to be possible by Hunter (131). He has also shown that the relative spread of root formation in stem propagation is a specific attribute. Semi-hard wood cuttings of citrus are propagated with much more certainty than those of hard-wood.

Selection of site and spacing

After selecting the site for raising an orange plantation, giving due consideration to the soil, climate and irrigation facilities, for which purpose the advice and help of an expert may profitably be sought in the beginning alone to avoid loss and disappointment later on, the land is first ploughed at least twice crosswise. Several thorough harrowings are then given and if time permits, the area may be left fallow for a season, and then sown to sann hemp (*Crotolaria juncea*) which crop should be buried in the ground as a green manure. If the land is required in the cold season, it can be brought into form in the following summer and green manured during the ensuing monsoon. The next hot weather may be utilised for taking pits at the required dis-

tances, and planting may be undertaken in June at the break of rains. If this is not possible the land may be ploughed and harrowed, and pits may be taken and left exposed during the hot weather for about two months. Planting may be taken up in the following June, in which case a full year is saved.

An appropriate spacing will depend upon the individual characteristics of the varieties selected and rootstock employed and their responses in respect to root growth. The penetrability of the soil has of course a marked influence on the rate of growth of the roots, but despite this fact varieties differ markedly in their spread and depth of root system. Until recently, the belief was common that the spread of roots corresponds nearly to the spread of the branches. A year old budded orange tree on a certain rootstock variety at Kodur (Madras) has been found to forage over a length of six feet radius from the trunk, whilst the spread of its branches hardly reached a radial length of one foot. In bearing plantations also, roots have been known to extend several feet beyond the branch spread. Till the root system of citrus trees on different rootstocks are studied under varied soil conditions, it is not possible to recommend definitely the optimum spacings for all the fruits.

The first principle underlying the spacing of fruit trees would be that the trees are to get enough growing space so that their branches just come into contact when they are of middle age. The habit of growth of trees, therefore, plays an important role in deciding upon the space to be given while planting. *Mosambi*, pummelo, grapefruit and Navel orange trees which have a spreading habit, are generally planted 20-25 feet apart. Trees planted fifteen or even eighteen feet apart are seen to overcrowd themselves in the Ahmednagar and Khandesh districts. Similarly, the practice of planting them at a distance of twelve feet each way necessitates the removal of the plantations very early, that is, when they are just about ten or fifteen years of age, as is noticed in the Saswad (Poona district) tract. It is, therefore, better and more profitable in the long run to allow at least twenty feet each way for these fruit trees. *Santra* trees which have an erect habit of growth are ordinarily planted at a distance of fifteen feet each way in Bombay Presidency. Such trees are seen to overcrowd themselves when they are advanced in age. If the soil be well drained and loamy, even *Santra* trees may be planted twenty feet

apart. In fertile soils under favourable conditions of climate and culture, even 25 feet spacing has been noticed to be scarcely adequate to citrus fruits. The *kagdi limbu* (lime) trees are also planted at eighteen to twenty feet apart in Bombay Presidency. If the soil is well drained and fertile, the trees may be profitably given an additional spacing of two to five feet each way. If on the other hand, the soil happens to be medium clay and rather sticky, the usual spacing as mentioned above may be adopted.

The spacing given to citrus trees varies markedly in the rest of India. In the Punjab, the general rule is to allot a twenty feet spacing for all kinds of citrus trees, but in the South of India where seed propagation is widely adopted, twenty-five to thirty feet spacing is given to sweet orange and *Santras*, and eight to twelve feet for acid limes. Recent experience at Kodur and elsewhere shows that 24 feet for budded sweet orange and 22 feet for acid lime are perhaps the best in South India.

Pits

Pits are best taken in the hot months and kept open until the following rains. Pits of three feet by three feet by three feet are usually taken for all citrus trees at the distance decided upon, as explained above. While digging the pits, the upper half of the soil is commonly heaped separately, and both heaps as well as the interior of the pits are exposed to the weathering action of the sun and wind during the hot months. Just before the rains are expected, the pits are filled up with the upper soil going first into the pits and the lower soil coming upon it. Both heaps of the soil are sometimes well mixed separately with the following mixture of manure per pit while filling the pits.

- 5 lb. bonemeal (or 10-20 lb. of whole unbroken bones),
- 100 lb. (about 4 baskets) of well rotten and powdered cattle manure, and
- 10 lb. of ordinary wood ash.

When the pits are thus filled a small peg is driven into the centre of each of them as a mark to guide the planting operation, which will follow after some days. Pits must necessarily be filled before the rains start, lest they get stagnated with water and their improved structure is spoiled by rain water. As pointed out for mangoes, it is suggested that no manure of any kind need be added to the pits in fertile soils. In other soils also,

it is best to allow ample time for the manurial ingredients to decompose in the pits prior to the actual planting. Addition of excess manure, or fresh organic manure to the pits at or just before the planting of trees is a practice that requires to be discouraged.

Healthy and vigorous budded plants are brought from commercial nurseries for planting, which is done when one or two rains moisten the soil and cool down the atmosphere. Arrangements may be made in time with reliable and registered nurserymen to reserve the required number of plants of high quality and they can be obtained just in time for planting. There is a widespread belief among the people that large-sized plants are preferable for planting and will bear fruits in a relatively shorter period. Very large and old plants, not only cost more to the grower, but also a large percentage of them suffer both in the orchard after planting and during transit. Webber (331) has shown that larger seedlings no doubt produce larger budlings, but it has to be remembered that the difference in the size of plants disappears rapidly as years roll on, and is found to remain only upto about eight years.

Planting

When plants arrive, they should be taken delivery of without delay and planted out in the field directly. While planting, each plant should be separated from the rest carefully, without damaging roots or shoots, and all injured roots and tender shoots neatly pruned off. Planting is done in the centre of the pits where the peg was driven previously by removing the refilled soil out just to accommodate the roots of the plants in their normal (not twisted or contorted) position. The soil is then put over and around the roots and pressed well with the feet of the planter. The plant should not be set down deep so as to bury the stem. It is a serious mistake to bury the bud-joint while planting, as this predisposes the trees to the attack of white ants and gummosis trouble later on. The bud-joint should be kept high above the zone ordinarily made wet by the irrigation water, in order to prevent the attack of gummosis at the bud region. Irrigation is given copiously immediately after planting. The tender plants are protected for a few weeks after planting from the heat of the sun by shading them with some kind of shelter made of green branches or so. These are removed after the plants revive from the shock of transplanting. In Rahuri

BASIN SYSTEM OF IRRIGATION IN A YOUNG CITRUS ORCHARD.

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(Ahmadnagar, Bombay State), *Mosambi* plants are sometimes planted in lucerne fields where they get ample water and manure and ample shelter from the sun's heat to start their life. After the plants establish themselves, lucerne growing is discontinued. In ill-drained fields this practice may be harmful, since the citrus trees may find that water applied to lucerne is much more in quantity and frequency than required to suit their needs.

In North India where there is a definite dormant period during the winter season, planting is done either in February or March, as soon as the severity of the winter weather shows signs of decline, or during August-September soon after the rains commence and well in advance of the cold season. In South India there is a longer planting season, commencing in July and continuing up to the end of January. Planting trees in February immediately before the ensuing hot weather is not resorted to.

Irrigation

After the first copious irrigation given immediately on planting, a lighter watering follows in four or five days. Thenceforth, irrigation is done in regular turns. If the area is under well irrigation, water is given once in six to eight days in the hot months from March to June, and once in ten to twelve days in winter from November to February. During the rains, July to October, water is given only when there is a long break of rains. But where irrigation is from the canal, the canal regulations cannot be changed to meet the requirements of orange plantations only, and the grower, therefore, irrigates his orchard whenever the authorities allow the canals to run. There is no doubt that this system does cause considerable inconvenience and loss to the grower, and in the best interest of the industry, the irrigation laws require to be changed to suit the needs of the planters wherever feasible. In canal areas, owing to the uncertainty of the availability of water, growers often let into the orchards as much water as they can when water is available, as the next turn of water may be uncertain and irregular. This practice often causes periodic stagnation of water in the soil, and brings about die-back and root-rot trouble. Too heavy irrigation is as harmful as lack or inadequacy of water. It is, therefore, safer to have well irrigation, as it can be controlled by the grower himself. Well irrigation is specially preferred when trees are treated for crop and when

quantity of irrigation water to be applied has to be regulated. Plantations of citrus get badly damaged in canal irrigated tracts, where they may be surrounded by heavily irrigated crops like sugarcane or rice. The percolation water of the neighbouring fields enters the citrus orchards through the lower layers of soil and always stagnates at the root zone. This situation prevents soil aeration and proper functioning of roots, as a result of which the trees suffer.

The practice of irrigating the citrus groves in this country has, in general, followed, certain arbitrary rules, especially in regard to the frequency of application and the amount of water applied. Most of the best kept orange orchards in the United States of America report average water usage of sixteen to twenty inches per annum. Some authors report that, in California, 9·2 acre-inches of water are used for Navel ranges from April to October, which in most years constitute the main irrigation period in that State. It has been suggested that alternate medium and light applications of water with not more than two heavy applications a year, would be the most efficient irrigation practice in Arizona. Thomas (306) states that as much as sixty acre-inches per acre have been applied in one irrigation season in some parts of California. This, however, is very rare. He avers that citrus trees are more sensitive to an excess of moisture than some other crops. The trees especially on heavy soils may get stunted due to excessive irrigation. Even in a grove where only seven applications for the season with a total of 18·5 acre-inches of water were applied per acre, he has pointed out that a considerable part of the water applied penetrated below the reach of the roots; carrying soluble plant food with it. He states that on heavy loam soils, a sixty-day interval resulted in better root development and more uniform distribution of soil moisture. Transpiration of trees averaged 16 inches in orange county while in the interior climatic zone of San Bernadino and Riverside it was 21 inches for excellent and good condition trees. Transpiration will vary from 50% to 80% of the total irrigation application (197).

Veihmeyer and Hendrickson (313) point out that on sandy loam soils of four to six feet depth in north Sandiego county the interval between irrigation during summer should not

exceed forty-five days, while in the lighter types of soil in orange county, the interval will range from thirty to forty days, and on the loam soils from forty to forty-five days. About one to one and a half times as much water was required when cover crops were grown as when the orchard was given clean cultivation. It is observed that citrus roots are most dense in the upper three-feet layer, and the upper foot contains the large majority of the roots. Thomas (306) states that citrus roots seldom penetrate below a depth of four feet. In soils less than three-feet in depth, it is estimated that fifty to sixty percent of the roots are in the top foot of the soil. The soil should be wetted at each irrigation to the depth in which most of its roots occur, even though the lower layers still contain some readily available moisture.

It is, therefore, clear that citrus trees develop a relatively shallow root system in most soils. Since plants will withdraw moisture from a given soil mass in proportion to the quantity of active absorbing roots in different depths, other conditions being constant, a knowledge of the rooting habit of the plant is useful in any intelligent soil moisture programme. In Arizona, grapefruit trees of four years of age on a light-texture soil had developed eighty percent of the total root system in the surface two feet of soil (240). In another study with mature citrus trees on the same soil type, where the extreme depth of root penetration was in the ninth foot, the major part of the root system was quite shallow. Another study in Arizona revealed that sixty-five to seventy percent of the absorbing roots of mature citrus trees are located in the surface two feet of soil (111). The same investigation shows that 31·6 acre-inches of water are applied in Arizona to Navel ranges in a year, and 40·7 acre-inches to grapefruit. Smith, Kinnison, and Carns (240) report that about thirty acre-inches of water per annum is applied to grapefruit trees on the Yuma Mesa in Arizona. Irregular watering or rainfall interferes with the normal growth and production of the trees. It has been observed that under moist conditions, in central and south India whenever trees are subjected to heavy rain, after a period during which water has been withheld, a flush of blossom results which may interfere with the fruit set in the normal season.

The most important methods of irrigation employed in citrus orchards, and in fact, in all fruit plantations are flooding, check

method, basin, ring and the furrow. The flood method consists of applying water all over the surface of soil. It is only possible on level ground and where water supply is abundant. It is obviously a wasteful method in young orchards, where the whole area is not occupied by the roots. With the check method, water is held around trees for a time by suitable bunds to induce percolation. This is a popular method of irrigation among the orange growers of South India. Bunds are run between every two rows of trees, with cross bunds at right angles to these so as to form a basin covering the entire area reserved for each tree. It has no place in young plantations, nor where cover or green-manure crops are raised. The preparation of beds entails much labour and where it is practised, it is intended to be a permanent feature not to be replaced or changed within short intervals.

Systems of irrigation

The basin system is perhaps the best method of irrigation in young groves. Small basins are prepared with bunds a little away from the drip of the young trees and these are connected with irrigation channels. The basins are widened gradually as the trees grow. Since investigations have proved that the lateral root extension of a tree is far beyond the spread of branches, it is necessary to make the basin larger by at least two feet than the tree-spread. On slopes, basin irrigation has special uses, since it facilitates control of water and retards the drift of silt from the upper to the lower regions. Such soils as may be moved are not lost, but tend to bank up at the lower end of each basin, ultimately creating a terrace-like effect and thus enabling more effective control of the water. This is so in the check system also.

The ring system is also recommended for young plantations, in areas which are likely to be affected with gummosis and other stem maladies. The ring method consists of making a small raised mound of earth near the trunk of trees, and by the outer side of this mound a ring about two to five feet in width with an encircling bund are made to hold water. Irrigation channels are connected to the rings by short furrows if necessary. Water is thus kept away from the trunk of trees, while it feeds the roots at their main feeding zones. The rings are widened periodically as the spread of the trees increases. The mound of earth near the trunk is also increased in spread but not in height. When the

tree-spread is so advanced that branches of adjacent trees touch, the rings give way to check, flood or furrow methods.

In South India a modified basin method is also sometimes known as ring system. In this, a circular bund is formed around the tree trunk, 2 to 3 feet away. Beyond this bund is the basin, which receives the irrigation water. This method does not seem preferable to the basin system, where a gentle slope is provided from the stem to the periphery of the basin, so that when water is let in, it first fills in at the periphery and remains there longer than towards the trunk. If the periphery is about four to five inches lower, water may not touch the trunk at all, or if it does, it will not remain in contact with the trunk for long.

The furrow method is very extensively practised in some citrus growing countries of the world. By this the entire soil surface is not wetted, and an even distribution of water ensured. It is suited to level or very slightly sloping areas. Four to eight or even more furrows are made at equal distance between the tree rows, with a double mould board plough or bund former. The water is admitted to the furrows from a main feeding channel. Water applied thus in furrows tends to move downwards with little lateral movement, the maximum lateral movement having been found in California to be about thirty inches from the centre of the furrow. The length of the furrows should not be too great, as otherwise moisture penetration is not satisfactory. On hill slopes, furrows exceeding 250 to 350 feet are considered undesirable.

Although four to eight furrows are ordinarily made between every two to three rows, additional furrows are also often zigzagged. In young tree plantations, two furrows one on each side of the row are also recommended in some parts of the world for four or five irrigations. But a combination of furrow and flood irrigation methods is suggested where there is any objectionable salt or alkali present in the soil.

Manuring citrus orchards judiciously is of very great importance in India. Enough experimental results on this subject have not yet been recorded to suit local conditions. However, from the general observations on the requirements of the plants from their early stages of growth, it is surmised that young plants need more of nitrogenous manures than bearing ones. In the earlier stages, that is, up to

Manuring

the age of five years, the plants grow well vegetatively, and establish a proper root system and head. This is accomplished by the supply of nitrogenous manures which help the trees to develop a rich green colour and healthy growth. Phosphatic and potash manures should be given some prominence, though not by any means to the exclusion of nitrogenous manures, after the trees come to bearing. Potash manures produce a balanced growth, maturity of shoot and fruits and help the formation of sugars and starch in them. Phosphatic manures stimulate bearing of fruits and promote root development and hasten maturity of plants.

No manure is given to the plants until one year from planting in the orchard except what may be given to the pits while or preferably before planting. A one-year-old plant may be given 20 lb. cattle manure, 3 lb. wood ash (for potash), 1 lb. bonemeal (for phosphoric acid) and 2 lb. of some kind of oil cake (for nitrogen). This dose of manures may be increased by equal doses year after year until the plants are five years old. After that, the oil cake may be reduced to five pounds only per year, the other doses remaining constant at the five-year dose throughout. In tracts where there is white-ant trouble, the oil cakes should be substituted by sulphate of ammonia or restricted to castor and *Karanja* (*Pongamia*) cakes only. These cakes are believed to deter white ants, being bitter and possibly also partially toxic to insects.

A good deal of literature on manuring of citrus trees is available regarding experimental work carried out in foreign countries. In many cases, the three manures already mentioned are given prominence and the doses are adjusted to suit the soil conditions. In cases of mottled leaf and lack of chlorophyll in the foliage, a zinc sulphate-lime mixture is sprayed on citrus trees one or more times. Copper sulphate in Bordeaux mixture spray is also sometimes applied in light doses to overcome the die-back or exanthema trouble in certain soils of Australia. A small dose of ferrous sulphate may also be given with advantage to correct iron deficiency, wherever that is suspected. Magnesium sulphate is yet another fertilizer found useful in some soils as those in parts of Florida. Lime and manganese applications too have a value under certain soil conditions.

The amount of soil nutrients removed from a good crop of oranges (about three hundred boxes per acre) has been estimated to be 43 lb. of nitrogen, 12 lb. of phosphoric acid and 49 lb. of potash (14). The latter two are less subject to loss by leaching than nitrogen, while the loss of organic matter was found to be very rapid. In humid regions, the loss is more than in semi-arid or arid regions. Again, since the roots of citrus are most dense in the first three feet of soil, greater depletion of soil nutrients occurs in this top layer than in others. In California, large increase in productivity of as much as 43 per-cent was obtained when only a small amount of fertiliser containing half a pound of nitrogen was applied in conjunction with a cover crop incorporated into the soil during winter. Batchelor (14) considers that in California, it is an extravagance to apply nitrogenous fertilisers more than once per year, and Webber (320) supports this view. No measurable effect was seen in California by the applications of potash and phosphate fertilisers.

Analytical data on nitrogen content in 36 bearing Valencia orange trees excavated over a two-year period at intervals of 3 weeks, reveal that nearly half the nitrogen is in the leaves, about one-tenth in the twigs and shoots, a quarter in the branches and trunk—about half of this being in the bark—and rather less than one-fifth in the roots. A maximum nitrogen content occurs just prior to the initiation of new growth in the spring and a minimum in mid-summer (50).

On the basis of a very comprehensive experiment with fourteen different fertiliser treatments on 2500 Washington Naval trees in South Africa, Anderson (7) has shown that a balanced nutrient solution with nitrogen and phosphoric acid is of the greatest importance. Ammonium sulphate induced very marked increase in weight of crop and number of fruits. A leguminous cover crop did not produce an increase in the nitrogen content of the soil or in the size of crop. Similarly, superphosphate, potassium sulphate and lime did not affect the size of the crop. High potash content caused high acidity in fruits, while a high phosphoric and calcium content in soils produced the reverse effects. The thickness of rind of oranges was increased by high potash content and decreased by high phosphoric acid. Except nitrogen, none of the elements

had any effects on sugar contents. Lord (156) advances the suggestion that a judicious increase in lime application to citrus groves is beneficial. In Florida, the citrus produced on soils of high lime contents has received consistently better prices than the rest. Ground lime stone screenings, wood ashes and raw phosphate rocks may furnish valuable sources of lime. Vosbury and Robinson (314) state that excess of nitrogen results in die-back and also causes thick-skinned and puffy fruits. Stable manure, on the other hand, may have a bad effect especially on trees growing on light soils when applied in large quantities. In small quantities, it is considered to be the best for citrus trees. On heavy soils, rich in humus, the application of lime is said to be beneficial, but too much of it may injure the soil. Withholding of potash has been shown to reduce the size of fruits in New South Wales (22). A mixture containing six hundredweight of sulphate of ammonia, three of superphosphate, and one and a half of sulphate of potash, applied at the rate of one pound of the mixture per tree for each year of tree's age till about the seventh year, when it would receive seven pounds, has also been suggested by some authors.

In South Africa (166), manures made from crop residues are recommended to be applied to trees at the rate of 200 lb. per annum per bearing tree or about eight tons per acre. But the exclusive use of this manure as an annual dressing is considered inadequate, and therefore, has to be supplemented by inorganic nitrogen application. On the other hand, five to ten cubic feet per tree of good stable manure or its equivalent in other organic fertilisers is reported to have given excellent results in some cases. Organic fertilisers, such as guano, showed no positive advantage over purely inorganic fertiliser mixture. Inorganic forms of nitrogen appeared to be particularly useful in revitalising declining trees. The value of the application of nitrogen and organic matter to citrus trees in South Africa as in California is also emphasised by Blatt (38).

Citrus growers in Western Transvaal are recommended to apply 150 to 200 lb. of well rotted *kraal* manure in June or July per bearing tree per annum. For Navel oranges an additional application of five pounds of sulphate of ammonia is recommended to be given in July together with ten pounds of super-

phosphate to large seedling trees, and somewhat less to fully bearing Navel and Valencia trees. Potash is advised to be applied in an inorganic form (5). Much of the nitrogen is to be applied during the spring, while a light dressing of nitrogen with phosphoric acid and potash during autumn is said to assist in maturing the autumn crop and future fruiting wood and benefit the crop (59). Prest (201) suggests that a suitable annual fertilising dosage for mature lemon trees would be six hundredweight ammonium sulphate, four of phosphatic fertiliser and two to three of potash fertiliser. Twenty tons of farmyard manure may also be applied per acre, or failing this, a green manure may be grown.

Some of the orange growers in the Rajampet taluk of the Madras Presidency apply a mixture containing 12 lb. groundnut cake, 9 lb. of fish manure, 3 lb. bone meal, and four to five baskets (100 lb.) of well rotted farmyard manure per tree per annum.

Growing and turning under of green manure crops are necessary where bulky organic farmyard manure is not available in sufficient quantities. This practice is of special value in young plantations, as it aids in the building up of a reserve of vegetable matter in the soil. Griffith (99) reports that in New South Wales, green manuring with a legume crop sown in winter increased the citrus crop yield by 33 percent. It was also found that although citrus trees did not respond to superphosphate, it is necessary to apply this fertiliser for securing a good growth of green manure.

It has been shown in Arizona, that the fruiting behaviour of citrus is more closely associated with the nitrogen supply during the winter and spring months than with any other nutrient material (9). Supplementary applications of nitrogen are reported to reduce shedding of fruits and increase the yield while heavy quantities of organic manures (20 tons per acre) are said to produce larger and somewhat coarser fruits and also to delay maturity. Nitrogen-starved trees produced fruits which coloured early and had a low acid percent, but the rind was thick and the juice content low.

Recent work in Holland has demonstrated that the amounts of vitamins C and A produced by plants largely depend on the amounts of nitrogen and potassium added to the growing

medium; increase in nitrogen in the medium being responsible for an increase in vitamin C and A while increase in potassium produced an increase in vitamin A and decrease in C. Such responses were, however, not obtained in America (83). There is enough justification for the belief that different manurial treatments bring about different effects on the quality of fruits, and as such, the subject is of great importance both for the grower and the consumer alike.

The furrow method of application of manures and fertilisers became popular for a time in some parts of the United States of America. The manure or fertiliser is distributed in furrows eight to fourteen inches deep running alongside the trees. The furrows for the first season may be run along both sides of the trees near the drip of the branches in the same direction as the flow of irrigation water. In the second season, they may be located similarly but at right angles to those of the first year. In the third year, the furrows may be made parallel to those of the first year, but nearer the centres of the tree rows, and similarly they may be placed the fourth year parallel to those of the second year. In later years, the methods of application depend upon the circumstances.

The application of manures in the Bombay Presidency is done at the commencement of monsoon in the case of young trees. When they come to bearing, the manures are applied while the trees are treated for bearing, by withholding irrigation and exposing their roots to induce flowering, excepting the nitrogenous manures which are best applied when fruits are set. This adjustment in applying manures coupled with frequent stirring of soil, helps the fruits to develop into large size and to become very juicy. Nitrogenous manures applied together with others while the trees are treated for flowering, are noticed to hinder flowering and to encourage vegetative growth. Slaughter house refuse when applied at the rate of two baskets (30-40 lb.) per tree of *Santra* and *Mosambi* of three years of age has been observed to produce good effect. One of the profitable results obtained was also by the application of 4 lb. of ammonium sulphate plus farmyard manure, the latter being essential to enable the trees to make full use of inorganic nitrogen supply (151).

In Rahuri (Ahmadnagar, Bombay State), *Mosambi* trees are manured at the rate of 5-6 lb. of castor or *karanja* (*Pongamia*) oil

A YOUNG ORANGE GROVE WITH A COVER CROP OF HORSEGRAM. *Facing page 183*

cake per tree of fifteen to twenty years of age before blossoming. This stimulates flowering and fruiting abundantly, specially in old trees. Farmyard manure is also given at the rate of two to four baskets (40-80 lb.) per tree.

Grove culture

Proper cultivation of the soil in citrus groves is as much necessary as in other orchards for providing an adequate soil aeration and also to prevent the weeds from robbing the soil of moisture and nutrients. Proper cultivation renders more water available to the roots by increasing the pore space and materially diminishing resistance to the rate of flow through soil. The extent of cultivation required to be given to an orchard is dependent on the soil topography and also on the kind of inter-crops grown. Removal of weeds, however, forms the main object commonly kept in view, but recent experience in the United States of America is that the weeding operation is usually overdone in most of the groves. It is not sufficiently realised that in some locations weeds serve as soil binders, by checking erosion and drift of the surface soil beyond the range of trees. That weeds can be utilised to the advantage of the trees by ploughing them under the soil and allowing them to decompose into soluble humus is also a point not to be forgotten. The old idea that the presence or absence of weeds is a measure of the citrus grower's ability is being dislodged, and the harmful effects of continuous clean cultivation is being increasingly realised (67). In many orchards, weeds serve as a voluntary cover crop and a worth-while addition to orchard soil. Realising their value, American citrus growers are now discarding the erstwhile practice of clean cultivation to the modified methods of giving the minimum cultivation that is necessary to incorporate weeds into the soil, except when inter-crops are raised. Deep tillage is likely to damage the roots of trees and should be resorted to only in young plantations. Continuous grove cultivation may result in the formation of hard pan or plough-sole, destroy the organic content, decrease bacterial life, and hinder the proper root penetration. Deep cultivation is necessary in young plantations where there is no fear of root injury, but should on no account be resorted to in older plantations, especially just prior or just following the blossoming period. Stirring the soil when wet, spoils the texture and retards the movement of water.

The orchard is ploughed or disced in the spring to incorporate the cover crop or weed growth with the soil. The soil thus made available is used to construct irrigation furrows. If rains occur before the first irrigation, or if there are plenty of weeds, it may be necessary to cultivate once again. In some orchards, cultivation is done once after the first irrigation but this is not done in all cases. The original furrows are left for several irrigations, if water supply costs less than removal of weeds. The orchard is cultivated and smoothened before harvest. Clean cultivation in dry season, combined with cover crops during the summer and rainy season, is the most widely used system in Florida (314). In Palestine, two hoeings per year (196) are considered indispensable to a citrus grove, one in the spring prior to the blossoming period (particularly in heavy soils) to aerate the soil, and another in autumn in order to hoe in the organic manure. In the United States of America, the trend is decidedly towards less frequent stirring of the soil.

Inter-crops

During the first three or four years of a citrus plantation, there is generally ample space between the tree rows to permit of raising subsidiary crops of some kinds of vegetables or of other crops of short duration. Such crops as *guar* (*Cyamopsis psoralioides*), *Bhendi* (*Hibiscus esculentus*), cabbage, knolkohl, cauliflower, tomato, and brinjal (*Solanum melongena*) are preferred for growing as inter-crops in orange and allied orchards. These inter-crops finish their life cycle in about five months from the start and may be grown either in the monsoon or winter. They do not require heavy and continuous irrigation. The land is left open for part of the year, which is highly desirable for proper hygiene of the land. These crops are of considerable economic importance, as they help the grower to meet sundry expenses as for example to pay for labour, manures, feeding cattle, etc. During the first few years, therefore, when the main plantation does not bring any returns, inter-crops are dependable to some extent for their income. In dry parts of the Bombay Presidency like Bijapur and in the East and West Khandesh districts, orange plants are sometimes planted at the required distance along with the plantations of banana. A dwarf short-lived type of banana, namely, the *Basrai*, is grown in these districts, and citrus plants get the advantage of being protected from the scorching sun during the first two

years of their life, if planted in banana plantations in these tracts. The banana plantations are removed within two years after citrus plants are planted and the latter are fairly well established by then to stand exposure to the natural heat of the tracts.

Inter-crops in citrus plantations should not be such as would require heavy irrigation and would occupy the land throughout the year, because the irrigation given to such inter-crops makes the land oversaturated and the main plantation suffers therefrom. Crops of lucerne (*Medicago sativa*), sugarcane and banana should be avoided as inter-crops as far as possible. Of course, the extremely hot tracts like the Bijapur and Khandesh districts are exceptions; and growing of such inter-crops during the first two years of the life of citrus plantations in these districts may at times be a desirable feature. Owing to the hot winds that blow during summer and the high temperature of the atmosphere, the effect of heavy irrigation to banana is not felt by the citrus plants. On the other hand, the latter are properly protected.

Pruning

There exists a lot of controversial matter in regard to pruning of citrus trees. One of the objects of pruning citrus trees is to give the plants the desired shape. Hodgson (119) believes that with practically all varieties "a certain amount of training" is necessary, if proper framework formation is to be secured. During the first two or three years special attention should be given to the selection of the framework of the trees as has already been pointed out previously. He recommends that three to four main scaffoldings be selected and these should be distributed as evenly about the trunk as possible. If they are selected early, and those not required are pinched or thinned, it is not necessary to head back these main leaders. When the frame-work branches are established, the only pruning that is necessary is the removal of suckers and the unusual vigorous water sprouts. He suggests that a good rule to follow especially in the pruning of young citrus trees, is when in doubt, leave it alone unpruned. During the first few years of bearing, pruning should be confined to the removal of suckers. Later, thinning may have to be done. As the trees grow older, it may be necessary to provide for the gradual renewal of the bearing area by occasional removal of older parts; but this must be done gradually. The lower branches bear fruits of poor quality

and therefore should be removed, but the tree should not be pruned too high. A foot from the ground is all that need be kept free from branches.

Ringing

In South Africa, ringing of citrus by giving a single circular cut knee-high round the trunk, through the bark to the wood just before the last petals of the main bloom have dropped gave substantial increase of yield. The greatest increase occurred only when low yielding or shy bearing trees had been girdled. Shamel and Pomeroy (237), however, noticed in California, a marked reduction in yield of previously ringed trees in the season after ringing. Little effect on yield was observed during the ringed year except during light cropped years.

Growing and fruiting seasons

Santra and *Mosambi* trees exhibit three growing seasons in the Bombay Presidency. They are June-July, September-October and February-March. The trees put forth new growth in each of these seasons, and often bear flowers and fruits indiscriminately in all of them, if they are left to nature. In order, therefore, to take advantage of the markets which are active in particular seasons, the orange growers of the Presidency give certain special treatments to the trees and make them bear only one but heavy crop in the year. The flowering seasons are called "*bahars*" locally. The purpose of these treatments is to check vegetative growth and to stimulate flower bud formation.

There are three *bahars*, for any of which the trees may be treated during the year. They are called the *Ambe* (February-March) *bahar*, the *Mrig* (June-July) *bahar*, and the *Hasta* or *Hatti* (September-October) *bahar*. The trees are usually treated for only one of these *bahars* in any tract, and to change the treatment from one *bahar* to another is a matter of considerable difficulty and inconvenience to the growers and also injurious to the trees themselves.

Treatment for *bahar*

When the orange trees are in their fifth year, they are generally treated for the crop for the first time. Flowers and fruits that may set earlier than that age are carefully removed before they develop, lest the early bearing should weaken the young trees.

The treatment for the *Ambe bahar*, so named because the flowering coincides with the flowering of the mango (*Ambe* or

Amb trees) consists of withholding irrigation water for about two months from the beginning of November to the middle of January. Irrigation is gradually reduced in the plantation by lessening the quantity of water given in each turn. The turn of watering which falls in the first week of November is half of the normal dose and the one that follows it is about one-third. From that turn irrigation is completely stopped. When the soil in the orchard dries up, the trees show signs of wilting and the leaves are shed. About the middle of December, the land is ploughed and harrowed. All dry shoots on the trees are pruned and the whole plantation is cleaned. If the trees do not show enough signs of resting by stopping water alone, as it often happens in heavy soils, the upper roots are exposed by removing the soil all round the trunk to a distance of three feet and to a depth of eight inches. The finer roots that get exposed in this area are neatly pruned close to the larger ones and any wound caused to the latter is trimmed and coal tar (liquified and cooled) is applied to it to prevent rotting. Roots half-an-inch or more in diameter are not pruned. This works as an additional check on the feeding of the trees, and stops their vegetative growth remarkably.

The roots are kept exposed for about ten days. The original soil is then replaced after mixing it with the annual dose of manure (excepting the nitrogenous manures as explained above) and the roots are covered up again. Water channels and basins are prepared and irrigation begins from about the middle of January. The first watering is very sparing, the second which is given after four or five days is more copious, and the third watering which follows ten days after the second is a full dose. Normal irrigation continues from then onwards. This precaution is essential because heavy irrigation all at once tends to force up vegetative growth. By the middle of February, that is, in about a month from the first watering, new shoots appear on which flower buds are seen. Flowering may continue till the middle of March when fruits set. Early in June, a dose of nitrogenous manure (oil cake as suggested above) is given to the trees and the soil in the basin is stirred frequently to keep the weeds down and to help the fruits to develop. In the loose, sandy deep soils of Rahuri, no root exposure is found necessary to induce flowering of *Mosambi* trees. Withholding irrigation for

about a month brings about the desired effect to check the vegetative growth of the trees. Trees of thirty or forty years of age are very common in this area and are seen in good health capable of bearing a good crop with normal irrigation and manuring. Older trees do require more manure than younger ones for bearing properly.

Fruits of *Ambe bahar* become ready for harvest in November-December, and the season may extend upto January and even to February. During Christmas the demand for oranges is fairly active and growers, therefore, take advantage of it.

Treatment for the *Mrig bahar* commences from April when irrigation is decreased gradually and stopped altogether by the end of that month. From the middle of May, the land is ploughed and harrowed and roots are pruned in the same way as in the case of *Ambe bahar* treatment about the end of May. By the middle of June, trees are manured and water channels and basins are prepared and the first water is given immediately, unless it rains by then. The operations are hastened up if signs of approaching rains are strong. First irrigation is sparing, the second is more copious and the third watering is a full normal dose, provided in all cases, rains do not intervene. By the middle of July, flowers are seen and fruits become ready for harvest in March of the next year.

As the fruits of this *bahar* are raw and acidic during the monsoon months when the *ophideris* moth breeds well, they do not suffer from their attack as much as *Ambe bahar* fruits do. During the months of March, April and May, there is always a good demand for the fruits and growers can sell their produce readily and profitably.

In the case of the *Hatti bahar*, however, no proper treatment of trees is possible owing to the preceding wet months. The trees cannot be forced to rest from vegetative growth, as stoppage of water is impossible because of rains. This *bahar* is, therefore, not treated for ordinarily, except when for some reason or other, the first two *bahars* are missed or are unsuccessful. When this *bahar* is obtained, it is poor and not remunerative.

The question as to which *bahar* to treat the trees for, depends upon several factors for its answer. Treating trees for any

Selection of *bahar*

bahar presupposes the availability of labour, irrigation water and market for the crop at

particular seasons. Pests and diseases also determine the choice of *bahar* in many cases. In the Poona, Ahmednagar and Nasik districts, orange trees are more commonly treated for the *Ambe bahar*, because in these tracts, orchards depend upon canal water which is assured even during the hot months when fruits set and develop. Labour is also available during the months of December to January when the *kharif* or rainy season crops are practically harvested. The presence of large cities like Bombay, Poona, Nasik and Ahmednagar assures a market for the fruits during the Christmas season. These facilities help the growers to successfully raise the *Ambe bahar* crop. Of course, this crop is damaged to a great extent by the fruit puncturing moth during the rains, but the other advantageous factors counterbalance the loss due to the moth.

In the Khandesh districts (as well as in the Central Provinces) the common *bahar* for which orange trees are treated is the *Mrig bahar* (so called because flowers appear when the sun passes through the *Mrig*, deer—constellation). The orchard commonly depends upon well irrigation, and the wells go dry in the hot weather. If trees are treated for the *Ambe bahar* in these tracts, they have to be watered properly during the hot months, which is not possible and the crop might fail. Resting of trees for the *Mrig bahar* means withholding of irrigation to the plantation during the months of April to June, and this synchronises with the scarcity of well water. Natural difficulties are thus overcome. The damage caused by pests during the monsoon months is also minimised, and the crop comes to harvest during the months of March-May when there is a good demand for the fruits. This *bahar* is therefore considered very advantageous in tracts which have to depend upon well irrigation and distant markets. Of course, there is considerable difficulty to get labour in May and June, when the preparation for the monsoon crops is in full swing.

As noted above, the *Hatti bahar* is not of much consequence and can be taken anywhere, if the first two *bahars* fail and if the weather permits. This *bahar* is successful only if there happens to be a long break in monsoon in the month of September, when the trees can be rested.

It is always highly desirable as already stated to treat a plantation for only one *bahar* and to stick to that *bahar* year

after year. By doing so, the trees get accustomed to definite seasonal treatments and they respond to them very well. Regularity is established in the cyclic order of operations of cultivation, and they become almost automatic. Changing treatments from *Ambe bahar* in one year to *Mrig bahar* in the other disturbs regular arrangements and causes economic loss. Trees treated for *Ambe bahar* in December of one year cannot be treated for *Mrig bahar* the following June, unless the *Ambe bahar* fruits are sacrificed. Resting the trees more than once a year is to be very harsh on them, and the trees may suffer in consequence. Similar is the case with trees treated for *Mrig bahar* of any year. If, therefore, it is desired to adopt *Mrig bahar* as a regular routine practice for future years in a plantation which is accustomed to *Ambe bahar* in the previous years, then it is desirable to drop all treatment for *Ambe bahar* in the December of one year, when treatment is ordinarily due, and instead to treat the trees for *Mrig bahar* in the following hot weather. This naturally means the loss of six months more between two *bahars*, which thus come at an interval of eighteen months. But this happens only once in the plantation and the loss caused thereby is not much. Changing *bahars* frequently is not desirable in the best interests of the trees, as well as of the proper income from orchards.

Changing the *bahars*

The citrus trees are the chief group of fruit trees which are artificially treated for the crop in this Presidency. Horticultural knowledge of exposing roots of trees and resting them is brought into practical play in this group more than in others. The cultivation of citrus trees is, therefore, considered to be of a distinctive character. It may be due to the equitable climate of the Deccan that the trees respond well to these treatments. In Sind and the Punjab as also in South India, the citrus trees do not seem to require any root treatment for flowering. The severe cold during the winter in North India perhaps forces the trees to rest during that period. As soon as spring dawns, the trees become active and rush into flush with flower and fruit buds. Irrigation is stopped during winter, but that is done because it is no use watering trees while they are resting, and not in order to force the trees to rest artificially from vegetative growth. The soil in citrus-growing regions in North India is alluvial loam and very deep. Withholding water alone is enough

if any measure is needed at all to rest the trees. Even in the Deccan, it is observed that trees do not require their roots to be exposed for resting in lighter shallow soils. Withholding of water for a period depending upon the nature of soil is enough to force blossoms under these conditions.

Root pruning of citrus trees is definitely a weakening process. While its value in regulation of crops cannot be denied under the Western India conditions, it has to be admitted that repeated annual pruning of roots may reduce the longevity of trees by progressively impairing their growth. It has been observed that when roots are pruned, a large net work of fibrous roots is formed from the cut ends during the first year of the operation. This power of root regeneration, however, gradually gets reduced by annual root pruning, resulting in a corresponding reduction in growth and production. In heavy soils, root pruning may produce some benefit by providing better soil aeration, but such a result is not likely in open soils. The deleterious effects of the practice of annual root exposure and root prunings are being realised in several orchards, particularly in southern and northern India. Even in the Bombay Presidency, it is advisable to find out how the effects of root pruning can be brought about by other and less severe orchard operations. At any rate, it appears necessary to suggest that root pruning may be resorted to infrequently once in two or three years in normal citrus groves, and annually only in the case of very vigorously growing and shy bearing trees, perhaps in heavy soils. In the latter case, it will also be better, if the soil is exposed farther away from the region exposed in the previous year, so that the roots are not hurt in the same place year after year.

A method of root exposure followed by heavy manuring in order to produce limes in the summer season is practised in Italy. It is said that this practice does no harm to the tree, provided it is carefully cultivated.

While treating orange trees for flowering, the period of stopping irrigation depends chiefly on the nature of the soil. If the soil is heavy and sticky, the trees do not show any sign of withering even if water is stopped for three or four months. Root exposure has also to be very severe in such heavy soils. In lighter soils, stoppage of water completely for about a month is found enough.

Kagdi limes

The cultivation of *kagdi* lime plants is receiving a great deal of attention in the Bombay Presidency in recent years. This fruit is considered to be of economic importance as it holds out a future for the lime juice or squash industry, apart from the use of fruits in their fresh condition.

Propagation by seed was the rule in the case of this fruit until lately. But it is now observed that if lime is raised by budding upon *jamburi* rootstock, the trees fruit earlier and the fruits become larger in size. The chief difficulty in budding *kagdi* lime is that many of its buds are accompanied by thorns and it is not easy to take out a thorny bud for insertion, with the prevalent method of budding. However, with some practice, the lower buds on a shoot can be carefully taken out and inserted with fair success. The method followed and other conditions of budding are exactly the same as for oranges.

In the West Indies, budding of limes on sour orange rootstock is widely practised. Sour orange is reported to provide a deep tap root for the limes, which when grown from seedlings, develops only a system of surface roots.

Lime trees on sweet orange or rough lemon (*jamburi*) have shown in California to make better growth than those on sour orange and trifoliate rootstocks. In Kodur, budded limes have yielded earlier and better harvests, trees on *Gajanimma* having performed the best.

In Dominica (109) sour oranges were resistant to disease and hurricane when used as rootstock to limes. The yields also have been much greater than on seedling trees.

Kagdi lime plants are planted 18 to 20 feet apart in medium black soils in the Bombay Presidency. In alluvial and more fertile soils, it is desirable to give them a larger space lest the trees get overcrowded in a short time. These trees are more spreading in habit than several other citrus trees. A plantation on the bank of the river Tungabhadra in the Kappat valley tract of the Dharwar district, was seen to thrive with a spacing of twenty feet each way and to present almost an overcrowded appearance. Trees in the Khandesh tract are also seen to spread out and occupy twenty feet space in a few years. In rich soils even 25 ft. spacing is, however, found inadequate in South India.

This fruit is very popular owing to its high medicinal value. It has become almost a necessity for the table in the daily life of Indians. The tree adapts itself to many kinds of soil and climate. It is perhaps more adapted to tropical conditions than the *Mosambi* or *Santra* orange trees. It thrives well in Sirsi (Kanara) with an annual rainfall of more than 99". It also grows well in the drier parts of the Deccan, as, for example, the Khandesh districts, with an annual rainfall of only 30". It seems to be more susceptible to frost conditions than other citrus trees, and that is one of the chief reasons for its limited cultivation in the Northern provinces of India.

In regard to its requirements of manures, irrigation and other items of cultivation, lime trees are akin to orange trees in many respects. They come to bearing a little earlier than the orange trees do, although a regular crop can be had from the fourth year onwards in Bombay Presidency.

Under natural conditions, the trees are seen to bear flowers all the year round, each flush bringing forth blossom. The period from flowering to harvest is about six months. This fact makes a difference in the economics of lime and orange cultivation in this country.

The chief harvest of limes falls in the monsoon when the demand for the fruits is very dull. Fruits have, therefore, to be sold cheap and the growers consequently suffer. During the hot weather, when fruits are in demand, the crop is scanty and prices rise. If, therefore, the trees could be forced to flower in the months of September to November, the fruit will be harvested in the months of March to May when the market for it is active. But this is difficult to adjust, owing to the rains in and preceding the September month. The natural *bahars*, namely, the *Ambe* and the *Mrig*, come to harvest in the rainy and winter seasons and the demand for the fruit in both these seasons is very low. In years when there is a break of rains during August and September, the trees flower soon after and fruits are harvested in March to May. But this rarely happens. Attempt is, therefore, being made to preserve the juice of the rainy season fruits in bottles for use in the hot weather, as is explained elsewhere.

At present, although the Presidency of Bombay has an area of about 2,600 acres under *kagdi* limes mostly spread over parts of the Deccan and Gujerat districts, the cultivation of this fruit is

not extending as much as it should have done. But the situation may improve when the lime juice industry makes a headway.

A summary of the breeding work so far carried out in citrus has been published by the United States Department of Agriculture (309). The difficulties in the way of breeding citrus fruits owing to the long time required to produce new varieties and to the phenomenon of polyembryony are clearly understood.

Citrus hybridization

The controlled pollination technique in citrus presents no special difficulties, mainly because of the relatively large size of the flowers and the fact that the pollen can be stored for over two months. With the multiplicity of forms of citrus existing in India and diversity of regional requirements, there is no doubt that ample scope exists for breeding new varieties of citrus with desirable combinations of fruit and tree characters now found in different citrus varieties. Such work is overdue and has to be undertaken on a nation-wide scale.

Mosambi and *Santra* fruits are ready for harvest generally in about ten months from flowering. Fruits develop a dull or yellowish orange colour in the Bombay Presidency. In the Ahmednagar and Khandesh districts, where the climate is drier and colder during winter, and hotter during summer, the fruits develop a fine golden orange hue when ready for the market. Harvesting is generally done according to market conditions. The orange fruits can be retained on the trees in the Presidency for over a couple of months and sometimes for even three months after maturity. Fruits of the older *bahar* are always valued higher in the market for their sweetness and finer quality as compared with those of the current season.

Harvesting of fruits

Some care is necessary at the time of picking the fruits and also in handling them at the time of packing and transportation. Clippers are used in most citrus growing countries to harvest the fruits, and pulling them by hand is prohibited. Fruits are then placed, not dropped, in small low trays or packing bags, and later transferred to suitable containers. In some countries, the fruits are allowed to remain in shallow trays for several days to sweat off excess moisture. Three days' storage in packing houses is recommended for Palestine oranges during which time the fruit shrinks, loses its surplus moisture, and its skin becomes less

sensitive. It is also possible to inspect satisfactorily fruits that have been previously damaged. If the fruits are to be stored for any length of time, dipping them in copper sulphate solution of 0·2 percent strength for one or two minutes is done. Packing of the fruits is done only after the fruits are thoroughly dried.

Colour does not usually afford a good indication of the maturity of citrus fruits. In cooler regions, citrus fruits have ample colour long before they attain the desired quality, while in warmer tracts the fruits become sweet some time prior to their attaining the ripe colour. Enclosing fruits in bags against pest attack, as is done in parts of South India, also hastens colouring of the fruits without simultaneously hastening the maturity. In the case of sweet oranges, the juice should be about 30% of the total weight of the fruit at the time of harvest. In some foreign countries, the sugar-acid ratio of the ripe fruit of different varieties has been determined and laws have been enacted to prevent the export of fruits that do not conform to the minimum ratio standard. In Palestine, the ratio between the citric acid and sugar contents is required to be in the proportion of 1:8 in sweet oranges at the optimum harvesting period. Citrus fruits are also artificially cured (or coloured) in some countries by the application of ethylene or acetylene gas. In Florida and elsewhere in the United States of America too, the total solids to acid ratio is commonly used as an indicator for ripeness, but it is realised that for oranges no one standard minimum such as, for instance—the 8: 5: 1 ratio is suitable for fruits from all regions. The titratable acidity determinations have recently been adopted in New South Wales, but this kind of test did not prove satisfactory in Jamaica. In South India for the fruits from seedling trees no satisfactory indication could be devised on the basis of sugar-acid ratio.

It is considered best to start picking on a fine day early in the morning, but after the damp or dew has all evaporated and the fruits are dry.

Excessive rainfall during the harvesting period leads to a congestion of the epithelial cells, a watery state of fruits, and rotting. Oranges, therefore, should not be picked during wet weather. It is also recommended in Palestine that the best method is to pick orange fruits from lower branches first to

prevent rotting, then of the higher branches to reduce windfalls, and lastly of the middle part of the tree.

It will be shown hereafter that the time of picking citrus fruits is important for successful storage. At present no authentic data on the best period of picking of Indian oranges are available. As there is a usual tendency on the part of the growers or orchard contractors to retain the fruits on the trees for a very long period in times of glut, investigations to ascertain the effect of such delayed picking on the storage life and on the subsequent crops, require to be undertaken. Such investigations will have also to take note of the effect of the orchard cultural treatments on the time of maturity.

The yield from sweet orange trees varies greatly according to variety and locality. In California, a report for 1936 shows

Yield

that the most profitable orchard had an yield of 260 packed boxes per acre, with a box value of $ 2·10 while the least profitable orchard had an yield of only 103 packed boxes with a value of $ 1·68 per box. In some parts of the Madras Presidency, an annual income of over Rs. 1,000/- per acre from citrus growing has been realised (182). This shows that citrus fruits play a very important role in the rural economics of this country at the present moment.

The results of the observations made in California indicate a depressing effect of a large crop in the amount of fruit in the succeeding crop, which effect increases with the length of time the crop remains on the tree. No consistent relationship between the amount of crop and fruit size is observed.

Grading oranges with the help of a cheap grading machine is an easy method, and has been attempted by some persons in

Grading

this country. A simple device for grading sweet oranges has been under test at Kodur (Madras). The machine consists of an inclined plank resting on stands and having a number of holes of different sizes made in it to permit the fruits to drop down through them as they are made to gently roll over. The smaller holes are made on the top of the plank and larger ones at the lower ends. Gunny bags are attached to collect the fruits that drop through these holes, the number of bags depending upon the number of grades (sizes) intended to be adopted. The bags are attached to the plank in a manner to permit a gentle

rolling of the fruits instead of sudden drop through the hole. With fruits like *Santras*, grading is possible only by hand, as no suitable and cheap grading machine has been devised yet for such fruits. Recently the Madras Agricultural Department has devised and popularised a more efficient machine for grading sweet oranges and another for acid limes, and both these have become very popular. The elaborate mechanical grading machines used in foreign countries cannot hope to engage the serious attention of the citrus growers in India for some years to come until co-operative organizations are developed on an extensive scale, and are able to handle very large quantities of fruits.

Grading of fruits as it is practised in India, and discussed herein, relates actually to the sizing of fruits only. Real grading, however, should include grouping of fruits according to colour and maturity stages. Both these points are taken into consideration to some extent by the retailers who resort to hand grading, but the cheap grading machines referred to above do not lend themselves for sorting out fruits of different colours and stages of maturity nor have any methods been evolved in this country with such purposes in view.

Packing of oranges

Santra and *Mosambi* oranges in the Bombay Presidency are generally packed in cylindrical bamboo baskets with little packing material for marketing purposes. The basket is closed by tying the bamboo lid on the top with a coir or twine piece. It is labelled and transported either by railway or by motor buses. The baskets ordinarily hold about three dozen fruits, and are sold in the market after opening their lids either in basket lots or in retail. The retailer displays the fruits well on the stall or his push cart as the case may be, and it is he who practically grades the fruits.

A few planters in North and South India have attempted packing their citrus fruits in wooden cases of the types adopted in foreign countries. The fruits are carefully picked, and their stems pruned off to a button. They are rubbed gently but well with a flannel piece to remove dirt sticking to the rinds, and then graded and wrapped in thin tissue paper, which is twisted off to a pig-tail. There is no standard system of packing, although the Californian standard package appears to be more popular than others.

No organization to sell citrus fruit in the Bombay Presidency is yet formed on the lines of the Citrus Exchange of Florida and California. Fruit is also not treated for its colour and appearance with ethylene gas as in those countries. Grading and improved methods of packing are being taken up by growers nowadays, and instead of packing them in fragile bamboo baskets, or loose gunny bags as heretofore, they are being packed in wooden boxes. It is, however, observed that during the season, *Santra* fruits are filled loosely in railway wagons and sent from Nagpur in the Central Provinces to Bombay, a distance of about 500 miles. It is true that the rind of oranges and lemons is tough, and can stand long railway journeys without much damage to the fruits but pressure of the upper layers of the fruits and rough handling in transit do affect them considerably and they are seen to fetch low prices in the market.

Marketing organization

In this country, the standing seasonal crop of citrus, as of other fruit crops, is usually sold to the contractors or middlemen, who in turn consign the fruits to commission agents in the various cities and towns. Some times the crops are sold to the middlemen two or three years ahead, in which case the orchards are either maintained by the grower or by the middlemen, according to the stipulations made in the agreement of sale.

Marketing of fruits

The commission agents may also undertake the purchase of the orchards on contract in addition to their own normal duties. The fruits on arrival at the warehouses or godowns of the commission agents are sold to the retailers or the public through private treaty or public auction. The latter method of sale is only resorted to in times of glut, or when the fruits are in an advanced state of decay. The retailers dispose of their fruits in shops or through hawkers. Some of the commission agents also maintain connections with a large number of hawkers, who collect the fruits for the day's sale from the commission agent's godown and credit the sale proceeds at the end of the day direct to the commission agents. This system is in vogue throughout the land with slight local variations. The large number of links in the chain and the manifold abuses that have crept in, in some parts in regard to the methods of sale and also in the matter of

payment of the full value realised for the produce to the consignees, have resulted in rendering the fruit growing industry in this country very uneconomic on one hand, and raising the value of the fruit available to the consumers to an abnormal level without guaranteeing a reasonable share of the high prices to the growers, on the other.

In March, 1949, rules for grading of citrus fruits were drafted and included in section 3 of the Agricultural Produce (Grading and Marking) Act, 1937 (I of 1937).

Cold storage experiments

Cold storage experiments conducted on Nagpur *Santra* fruits at the Ganeshkhind Fruit Experiment Station, Kirkee have shown that these fruits can be well preserved at low temperatures of about 40°F for three months. Results of investigations carried out in other countries have been summarised by Wardlaw in a series of articles, and these indicate that a considerable temperature range is cited in different countries for the cold storage of citrus fruits. The time of picking oranges in relation to maturity is indicated to be of extreme importance (10). In Trinidad, 40°F is advised for most sweet orange varieties. Fawcett (81) recommends 38° to 40°F for Californian oranges, but advises a range of 32°F to 40°F, to combat the stem-end rot. For Rhodesian oranges, Bates (18) cites 40°F as the most suitable storage temperature. That the keeping quality in storage is considerably affected by cultural treatment such as girdling and application of nitrogenous fertilisers at certain periods is well-known and has been proved by the Arizona experiments (9).

There is very little information available at present on the gas storage of citrus fruits. On the basis of his work on gas storage of Valencia oranges, Samisch (225) states that "It would seem that gas storage of oranges would be of minor practical importance", in view of the fact that the difference in change of composition of the edible portion of Valencia oranges between different extremes of gaseous environments was very small. The CO_2 treatment produced also a specific injury to the rind, while storage of oranges at low temperatures did not cause any harmful effects and in fact was effective in the control of decay.

Oranges and limes are preserved in foreign countries in large quantities and in a variety of ways. In India, however,

the only kinds of products that were prepared out of these fruits till about a decade ago were pickles, syrups and squashes.

Preservation of citrus fruits

Preserving them as marmalades, candied peels, juices, citric acid, etc., was almost unknown in this country till recently. Lately, owing to the efforts made by the Agricultural Departments all over the country and more especially due to the transient demand during World War II, the public are being awakened to the possibilities of developing a highly lucrative industry in preserving these fruits. A beginning in the manufacture of some of the latter products has been made in different parts of the country. The marmalades of oranges and other citrus fruits, lime squash and lime cordial, lime pickles, etc., made by these firms are becoming gradually popular with the masses. The market for these products is yet to be developed on a larger scale in India. The existing demand has been met in the past by products imported from abroad at a high cost. Such imports have not ceased even with the protection given by the Government. A great deal of headway remains to be made in the matter of economy in the cost of production and towards improvement and standardisation of quality.

Of all the citrus fruit products, orange squash, especially from sweet oranges, is perhaps the most appealing, though rather expensive. The method of preparing this is explained below :—

Orange squash

Fully ripe oranges after thorough washing are either cut into halves (in Maltas) or peeled by hand (in *Nagpur Santra*). The juice is extracted with a juice extractor, a revolving cone made of glass, monel metal or such non-corrodible metal in the case of sweet oranges or meat-mincer type squeezer in the case of loose skinned fruits, and then strained through a coarse muslin cloth or a pulping machine. For medium sugar content squash, the ingredients are added in the following proportions: juice: sugar: citric acid = 10 lb.: 7 lb.: 4 oz. For high sugar content squash the proportions are: juice: sugar: citric acid = 10 lb: 15½ lb.: 7 oz. Edible colour (Niagra concentrated orange powder or Edicol A. G.) at the rate of 1·5 gms. per 100 lb. of the squash is added by dissolving the same in a little of water and mixing it thoroughly with the squash. The preservation of the squash for long storage is effected by the addition of potassium metabisulphite at the rate

of one ounce for 100 lb. of the finished product and packing in sterilized bottles which should be sealed air-tight.

Lime or lemon squash

The lime and lemon squashes are popular beverages and relatively cheaper than orange squash. They are prepared as follows: Fully ripe fruit after washing is cut into halves and the juice extracted with an extractor. The straining of the juice is done through a pulping machine or a coarse muslin cloth and the proportions of the ingredients for medium sugar content squash are: juice: sugar: water=4: 5: 3 and for high sugar content squash: juice: sugar: water=1: 2: $\frac{3}{16}$. The ingredients are mixed thoroughly and the prepared squash is preserved by the addition of one ounce of potassium metabisulphite per 100 lb. of the prepared squash and bottling in air-tight sterilized bottles.

Lime juice cordial

A clarified fruit juice, in which all suspensions are eliminated, sweetened with appropriate quantity of sugar is known as cordial. The juice of limes or lemons is strained through a thick cloth and stored in deep non-corrodible vessels with potassium metabisulphite added at the rate of an ounce per 100 lb. of the juice. For quicker clarification, special reagents are used. The clean juice devoid of all suspended matter which settles at the bottom after about a month's storage, is syphoned and mixed in the proportions—juice: sugar:. water=4: 5: 3. The additional quantity of potassium metabisulphite (proportional to the weight of sugar and water) is added and packed in sterilized bottles and sealed air-tight.

Lemon barley water

To prepare lemon barley water, a thick paste of the barley water is first made out by thoroughly mixing 3 oz. of barley flour (Robinson patent barley flour) in one gallon of hot water. The paste is then cooled and sugar added to raise the Brix to 50°, when it is strained through thick cloth. This is then mixed with half the quantity of lime or lemon juice, strained through a coarse muslin cloth, and potassium metabisulphite added at the rate of 1 oz. per 100 lb. of the prepared product. It is placed in sterilized bottles and sealed air tight.

An addition of 10% mango pulp to citrus squashes as a source of colour instead of dyes is reported to have proved very satisfactory at Lyallpur. While the mango flavour becomes imper-

ceptible after about 4 months, the colour is fully retained. The mango pulp was prepared during the previous summer and stored either with 0·1% potassium metabisulphite or after pasteurization.

Use of rind

It is suggested that the rind of the fruits which are crushed for the juice may be well utilised by salting in preparation of pickles as well as a flavouring agent. This by-product is very bulky and can be sold cheaply and with good profit (34).

Candying of citrus peels

The halved citrus peels (Malta, grapefruit and lemon) can be utilized to produce a welcome addition to the edible by-products from citrus fruits. These peels are cleaned of their rag by means of special spoon-shaped knives and then washed thoroughly. Curing of these peels is done by soaking them in 2% common salt solution, adding an amount of common salt so as to increase the strength of brine by 2% after every 24 hours till a final concentration of 8% common salt is reached. At this stage the old 8% brine is replaced by a fresh one to which potassium metabisulphite is added as required and the whole stuff stored in well closed air-tight vessels for at least six weeks. After this period the salt-cured fruit is boiled till it becomes soft and most of the salt absorbed by the peels is removed. This is then washed in fresh running water and drained over a large sieve. The drained and prepared peels are put in boiling 30° Brix syrup (containing 0·1% citric acid to effect partial inversion of sugar) and heated to boiling. The peels are covered with a lid so that they are left completely submerged in the syrup. Next day the syrup is drained off and enough sugar added to bring the sugar concentration to 35° Brix. The syrup is heated to boiling and poured on the peels for absorption of sugar during the next 24 hours. The sugar concentration of the condensing syrup is increased by 5° Brix. After this it is increased on alternate days in similar manner till the syrup strength records 75° Brix, when the peels are kept submerged in the syrup for 3-4 days, after which they are drained and dried preferably in the shade.

Citrus marmalade

Marmalades of good quality can be prepared from a number of citrus fruits. A method of preparing the product is described below:—

Only the upper yellow portion of the skin of the thoroughly

Ascorbic acid content of citrus fruits

Values expressed as milligrams per 100 grammes

Food	Description	Quantity of ascorbic acid: Dye method	Quantity of ascorbic acid: Iodine method	Year reported	Investigator
Orange		60	71	1933	Bessey and King (26)
	Unripe	45	—	—	
	Ripe	50	—	1935	Giroud, Ratsimamanga and Lebloud (98)
	Ripe, weight 58·85 g	51·5-54·3	—	1935	Ranganathan (203)
	C. aurantium pulp	18	24	1935	Ghosh & Guha (97)
	Mandarin (*C. nobilis* delicose)	31·5	—	1935	Ahmed (1)
Orange-stored	16 hrs. wt. of average 58·85 g	50·7	—	1935	Ranganathan (203)
	24 ,, 1·25 g waterloss	61·6	—		
	48 ,, 2·29 g ,,	60·1	—		
	72 ,, 3·18 g ,,	57·2	—		
	96 ,, 3·88 g ,,	53·0	—		
	144 ,, 5·26 g ,,	60·8	—		
	216 ,, 6·91 g ,,	54·6	—		
	264 ,, 8·43 g ,,	56·4	—		
	312 ,, 10·04 g ,,	61·6	—		
	384 ,, 10·98 g ,,	47·48	—		
Lemon	*Citrus limonia*	42-65	—	1934	Bacharach, Cook and Smith (12)
Lemon albedo	—	46	51		
Lemon flavedo	—	210	220		
Lemon peel	—	100	—		
Grape-fruit (*Citrus grandis*)	—	53	53	1933	Bessey and King (26)

Composition and vitamin content of orange and lemon juice worked out by Mottram and Graham (178)

	Grammes per 100 gms.				mg. per 100 grammes								Acid base balance per 100 gms.	Vitamins I.u. per 100 grammes		
	Protein.	Available carbo-hydrate	Un-available carbo-hydrate	Calories per 100 gms.	Na	K	Ca	Mg.	Fe.	Cu.	P.	Cl		A	B_1	C
Orange Juice	0·6	9·4	0·0	41	1·7	179	11·5	11·5	0·30	0·05	21·7	1·2	45	300	—	400
Lemon Juice	0·3	1·6	0·0	8	1·5	142	8·4	6·6	0·14	0·13	10·3	2·6	38	—	—	520

washed fruit is removed with a sharp knife or a peeling knife (except *Santra* which can be peeled by hand), leaving as much of the white portion of the peel as possible. The peeled fruit is then cut into thin slices to which enough water is added so as to cover the skins. It is then boiled for half an hour to extract pectin and the extract strained through thick cloth or jelly bags. The pectin test is performed with a jelmeter or with 95% alcohol and the degree of richness of the pectin determined. A calculated amount of sugar is added and the mass heated to about 218°F, when fine peel shreds are added and the heating continued to 222°F, which is the closest temperature to the jellying point. The marmalade is poured hot into clean sterilized screw cap jars, scum is removed and the mouths of the jars covered till completely cooled and set. A thin layer of paraffin wax is applied at the surface to prevent the product from the weeping effect and spoilage.

Food value

Pectin forms an important constituent of citrus fruits and with the fruit acid is responsible for the set of jelly and marmalade, as has already been shown above. It can also be extracted in the form of powder. Citrus fruits as a group are reputed for their healthful dietetic properties. They are generally a rich source of calcium. The calcium contents of oranges and orange juice have been shown to be affected by the variety, soil and fertiliser. With the membrane surrounding the section of the orange the calcium content is said to be almost twice that with the membrane removed. Oranges are also a fair source of Vitamin A, and an excellent source of vitamin C. Extensive tests in Arizona showed that fruits from trees so managed as to give a low nitrogen content at harvest consistently contained 20-25% more ascorbic acid than those from trees with higher nitrogen level. Grapefruit juice gave a negative correlation co-efficient between nitrogen and ascorbic acid. Also see pages 203, 204 and 206.

Diseases and pests

Citrus trees in the Bombay Presidency suffer from several troubles both pests and diseases of organic physiological nature. The commonest of these are the die-back, gummosis, canker, root rot, cracking of fruits, the fruit sucking moth, stem borers, scale insects, aphis and the lemon caterpillar. A type of chlorosis and mottle leaf are also seen. The root rot of citrus trees, the cause of which is

Read and his co-workers (205) analyse the citrus fruits in Shanghai as follows:

Name	Edible portion.	Water	Protein	Fat	Carbohydrate	Crude Fibre	Calories 100 gms.	Ash	Ca	P	Fe	K
Orange (*Citrus nobilis*) Lour var. ..	80	86·76	0·58	0·35	11·55	0·40	53	0·36	0·020	0·008	0·0020	0·142
Lemon (*Citrus Medica* L.) var. Limomum Hoak	65	89·37	0·82	0·89	7·84	0·65	44	0·43	0·033	0·024	0·0006	0·193
Pummelo (*Cirus decumana* L.)	61	84·82	0·74	0·56	12·20	0·82	58	0·86	0·041	0·043	0·0009	0·332

Average composition of edible flesh of fruits by chace et al., quoted by Winton (348) is as below:

	Solids total %	Solids Insol. %	Protein %	Acid % (citric)	Invert Sugar %	Sucrose %	Ash Total %	Ash Alk.
Orange ..	11·38	2·70	0·72	2·65	4·45	5·29	0·57	..

TRENCHING AS A REMEDY AGAINST DIE-BACK IN AN AFFECTED *MOSAMBI* ORCHARD AT KOLHAR.

Facing page 207.

not definitely known, has been spreading fast lately and devastating several flourishing orchards.

Different forms of citrus die-back prevalent in peninsular India have been described. It appears that *Mosambi*, *Santra* and grapefruit are the only three types of citrus which are mostly affected. This disease has assumed very great importance in India as a great deal of damage is done to the plantations. The disease has taken a very large toll of citrus orchards especially when they are raised without proper selection of the soil. Defects in cultural treatments are also found to predispose the trees to this trouble. In fact, several factors acting singly or jointly are found to induce this disease in most of the groves.

Citrus die-back

The die-back trouble seems to have been prevalent in the Bombay Presidency for a long time. Its seriousness was first recognised by the Bombay Agricultural Department in about the year 1912. Certain preliminary trials in treatment were made about the year 1921. A study of the trouble combined with a survey of the conditions under which it occurs, and regular experiments to reproduce the trouble under controlled conditions were undertaken during 1924-25. From observations recorded by the Department of Agriculture, it is evident that the soil and climatic conditions are closely associated with this disease. The nature of this disease is physiological since no organism is found associated with it. Remedial measures taken with a view to correcting physiological disturbances have been partially successful.

Symptoms of die-back have peculiar characteristics of their own. Whole plantations, individual trees or trees in patches may be affected. The disease usually makes its appearance after the first or second bearing. Younger trees may also be affected under extreme conditions. The first symptoms appear when the terminal leaves and shoots turn yellow. This yellowing is different from simple mottling or the yellowing of ripe leaves. The symptoms appear all at once in the new shoots of a fresh flush. The trees may apparently be in perfect health, before the flush, but all of a sudden they begin to produce pale tender leaves which do not mature at all. They fail to develop the normal green colour. After a time, they attain considerable turgidity and remain stunted and pale. Often, variegated leaves

are also observed. The variegation is caused by regular stripes of green and yellow colour alternating one another. The green colour is mostly seen alongside the main veins indicating a collection of chlorophyll matter on either side of such veins while the yellow stripes are deficient in chlorophyll. All the new sprouts, however, may not exhibit this symptom. The new sprouts arising on one or more main branches only may show the symptom in the beginning, but subsequently, more branches will be attacked, while those that were already attacked get worse. Again, when the symptoms appear, they do so not on one or two or a few individual fresh sprouts in a sporadic manner, but on all the new sprouts on a main branch. The unit of attack is, therefore, a main branch of a tree and not an individual sprout or two. From the time the first attack is seen, it may take from one to two years before the whole tree is seen to suffer. This is why in the earlier stages of the trouble, it is seen on some parts of trees only, while the others remain apparently healthy. The further symptoms are the death of yellow shoots and leaves extending gradually to the lower parts with a dimunition in the bearing capacity of the affected tree. Fresh growth on an affected branch is very sparing and new sprouts never develop normally either in colour or in vigour. The region on the trees in which new sprouts appear is pushed downwards as it were, and dormant buds on the thicker stems just below the dead parts come into activity. In a tree of advanced infection, it is only the basal stems of the main branches that survive with a few undeveloped yellow multiple sprouts on them. At this stage, which is reached in about four years from the time the first attack is seen, the tree cannot bear even a single fruit and it dies soon after. The formation of gum-pockets and dark excrescences as described by Floyd (86) in the United States of America is not seen under the conditions obtaining in the Bombay Presidency. While these are the prominently visible symptoms of die-back, a detailed examination reveals that every part of the affected tree displays a characteristically deteriorated condition of health. When die-back appears on the branches, the roots are seen to shrivel and are reduced in number. The roots may disappear under dry conditions and may rot under conditions of stagnation of water. The internal structure of the branches as well as of the roots undergoes very great changes and everywhere disintegra-

tion and rotting are seen. With the symptoms progressing rapidly, the whole tree dies in about four years.

From the investigations carried out so far, by the Bombay Department of Agriculture, it would seem that certain soils and soil conditions predispose the plants to die-back, as for example,

1. Soils containing an excess of lime;
2. Soils deficient in plant food;
3. Soils deficient in aeration;
4. Soils having a hard subsoil;
5. Soils in a water-logged condition.

Hence the precaution to be taken against this disease appears to be such measures as will eliminate or minimise the defective conditions. Similarly an orchard suffering from die-back can be restored to health by adopting measures that will correct these pre-disposing factors.

Bates (17) summarising the results of the investigations on the die-back of citrus in South Africa states that, (i) damp and cloudy weather with heavy rain at intervals, (ii) growing dense cover crop of sann hemp in close proximity within a radius of six feet from the tree, and in many cases higher than the young citrus trees, and (iii) too many young lateral shoots allowed to develop between the union and head, contribute to the incidence of this disease.

Pot experiments have shown that the application of leaf mould is an effective treatment for *Mosambi* orange trees when they suffer from die-back in limy soils. In orchards where die-back appeared as a result of water-logging caused by over-irrigation, the trees had improved when the water was drained away by a deep open trench. Subsequent application of a good dose of manure aided their recovery. Under dry conditions of soil, loosening the soil has resulted in the improved health of the trees accompanied by good bearing. A carefully conducted experiment at the Ganeshkind Botanical Gardens (now the Ganeshkind Fruit Experimental Station), Kirkee, on about 110 five-year-old trees, has shown that the application of manures and trenching have all curative as well as preventive values, irrespective of the degree to which the trees have responded to them. The application of sulphate of ammonia at intervals of three months induced the best growth of the trees,

and helped diseased trees to recover to the greatest extent. Opening trenches three feet deep and two feet wide in the centre of the rows of trees planted 20′ apart also induced the recovery of the trees to a great extent, and stimulated profuse growth on the trees. Leaf mould at the rate of fifty pounds per tree, came next in order of merit in improving the affected trees. Addition of lucerne-field soil to the trees did not prove to be effective.

It may be noted here that these methods have been readily taken up by growers with considerable advantage in improving affected orchards. Sahasrabuddhe (223) records a very interesting experiment in curing die-back of oranges in black soil in the Ahmednagar district. The treatment consisted of opening trenches to improve the aeration of the soil. He treated an orchard of about 400 trees of *Santra* suffering severely from die-back. Trenches were opened out in between the rows wherein water and manure were given to the trees. The dose of manure given per tree was as follows:—

Niciphos ..	.. 1½ lb.,
Sulphate of ammonia	.. 1½ lb.,
F. Y. M. ..	.. 2 baskets.

The trenches were then closed and irrigation given in between the trees in broad furrows where a cultivator was worked after each irrigation as soon as the soil came into condition. The trees bore a full crop in this grove. At Kolhar in the same district and under similar soil conditions a Santra orchard suffered from over-irrigation verging on stagnation with canal water, resulting in serious die-back. The plantation improved when two to three feet deep trenches were opened out to drain away the excess of water.

Gummosis disease

Gummosis is another serious disease of citrus in the Bombay Presidency, and is known to result in a very considerable damage in the absence of a suitable treatment. The cause of this disease is a fungus parasite (*Phytophthora palmivora*) which lives in the soil. Under favourable conditions of soil moisture and temperature, the fungus produces spores each of which produces a swarm of spores which swim about for sometime—and then give rise to fungus threads (hyphæ). These threads enter the plant at the bud-union but cannot penetrate the *jamburi* rootstock since it

is resistant to the disease. If *Mosambi* trees are therefore budded high enough on *jamburi*, there is practically no danger of the disease even under conditions of fairly excessive irrigation or rain. After the fungus has entered the bud-union, it invades the bark and the invaded region extends over considerable distances upwards, but over smaller distances sideways. The bark is killed through to the wood, and a watery substance is formed underneath it. As the watery substance accumulates in large quantity, the pressure increases ultimately rupturing the bark longitudinally. Large quantities of gum are exuded from the vertical cracks. If the bark in the invaded portion is scraped with a knife, the inner surface shows a brown discolouration, which gradually fades at the margins of the invaded zones into the normal colour of the sound tissue. It is at the margins of these zones that the fungus is most actively growing. If the disease is allowed to progress, and more than two-thirds of the stem is girdled then no treatment is effective. It is, therefore, recommended that the diseased plants should be treated soon after the exudation of the gum is noticed.

Apart from a curative treatment, gummosis of citrus can be prevented by adopting suitable preventive measures. (i) As has been shown above, the fungus enters the plant at the bud-union. It is, therefore, very important to plant young trees budded high on rootstock of *jamburi* or other resistant variety. Budding should not be less than 18 inches above the collar of the rootstock. (ii) Soil should not be piled up too high around the trunk to protect the collar from too long contact with irrigation water, because this provides very favourable conditions for the penetration of the fungus. This precaution is very important in plants budded low, or planted deep in the soil, since the fungus can enter the plants at the bud-union from the soil which harbours infection. The earth should, therefore, be removed from the base of the trunk and piled into a small encircling mound, so as to prevent both soil and irrigation water from coming into direct contact with the trunk. (iii) Excessive flooding of orchards should be avoided, as this tends to create water-logged conditions in heavy soils.

Unless the disease is so far advanced as to girdle two-thirds of the trunk, it is possible to cure it. The extent to which the bark is infected should be ascertained and the surface should be

scraped with a sharp knife. The diseased bark should be cut carefully through to the wood with the knife, care being taken to cause no injury to the wood by this operation. The cut should be extended at least half an inch beyond the diseased zone on all sides. This operation is the most important step, as elimination of the diseased bark is an essential feature of the treatment. Creosote oil having a strength of 25 to 30% should then be applied with a strong brush to the exposed wood. The application should be thoroughly made at the sides. Creosote oil should be allowed to penetrate into the wood and the bark at the sides of the cut area so as to kill the fungus. After the surface of the wood is dry, coal tar painting is to be done on the exposed parts only to protect the same from wood-rotting fungi. If the diseased bark is not carefully removed, the disease may reappear at the side of the wound. In such cases, it will be necessary to cut out completely all the diseased bark and treat the fresh wound as stated above.

The creosote oil is guaranteed to contain 25-30 percent high boiling compounds of tar to which it owes its fungicidal properties. It has been found that the cost of treating a tree varies in relation to the extent of the wound to be treated. On an average, however, more than five hundred trees can be treated with one gallon of the oil. Unlike carbolic acid which causes burning to the stem when used in more than the desired quantity, creosote oil causes no injury to the plant tissues.

Canker

This disease is also serious and is gradually spreading. Brownish pustules appear on leaves, stems and fruits. The trouble is most common on *Kagzi* lime trees. The causal agent is the bacterium, *Pseudomonas citri*. The pustules are more severe in places of contact of two or more fruits. It is not possible to cure citrus canker but it can be prevented from spreading by picking off all affected leaves and fruits and by pruning affected twigs. As the trouble appears on the smaller twigs and then spreads downwards, pruning of the twigs can be done without causing much damage to the trees in the earlier stages of attack. The affected parts which are thus removed should be burnt, and the whole plant should be sprayed with Bordeaux mixture (5: 5: 50) to prevent further infection. Citrus canker is a notorious trouble in almost all citrus growing countries (81). It probably originated

in India or Java, whence it spread to other countries. In India, it is seen in the Malta orange plantations of the Punjab and in the citrus groves of the Bombay and the United Provinces, Bengal, Assam, Madras and the Central Provinces. The damage caused by it is, however, not much, if the trouble is controlled as above in its very early stages.

Root-rot

Citrus trees, especially *Santra* and *Mosambi* are often seen to collapse suddenly within a month or two in thriving plantations. Trees may be affected individually or in patches and may turn yellow and wilt. In a few months they succumb to the trouble. When their roots are examined, they are seen to be rotting and their bark peels off lightly and the rotten portion darkens in colour and may smell badly. Root-rot has also been found to play havoc in several orange plantations in South India. Several plantations have lately been devastated by root-rot. This disease is being studied further. It may be only stated at present that as soon as the tree is found to wilt, for no apparent reason, it should be at once uprooted and burnt on the spot. A trench may be dug all round the base of the tree enclosing the region of the roots, and the dug-up soil of the trench may be heaped in the enclosed area. The spot enclosed by the trenches may be sterilised by burning brushwood or other material and in this way the spread of the disease may be prevented to some extent.

Withertip

In the Punjab, a disease known as withertip caused by *Colletotrichum gloeosporioides* is widely prevalent. As this disease is generally confused with citrus die-back, it is necessary to understand the characteristic symptoms that distinguish the two diseases. The withertip disease causes characteristic black dots all over the dead parts of the affected twigs, which are sharply demarcated from the healthy parts. These dots are not seen in die-back. Bordeaux mixture spraying has proved most effective as a control measure against withertip.

Mottle leaf

The characteristic symptoms of the mottle leaf of citrus are the appearance of irregular patches on the leaf surface, each arising first as a chlorotic spot, and then widening and deepening in colour. The veins remain green but all the rest of the diseased leaves develop a yellowish colour. In serious cases, the tree is dwarfed

and the yield declines. This disease can be corrected by the application of zinc sulphate or sometimes by ferrous sulphate. Best control can be effected by spraying the trees with a mixture of zinc sulphate (10 lb.), hydrated lime (5 lb.), actin (¼ lb.), or solol (½ lb.) with 100 gallons of water. The zinc sulphate should be 98% pure. Hydrated lime is first added and then the zinc sulphate. This is followed by actin or solol, and the mixture is briskly stirred before use. Spraying with ferrous sulphate 0·0001 percent solution has also been found efficacious in some cases. Actin and solol do not seem to be essential in all cases.

The trouble is supposed to be caused by lack of enough zinc or iron compounds in the soil, which prevents normal chlorophyll formation. Commercial zinc sulphate is almost always closely associated with the presence of ferrous sulphate as an impurity in it. A sample from the Baroda market sold as zinc sulphate showed on analysis the presence of iron sulphate to the extent of 0·005% calculated as Fe, or 0·0135% as iron sulphate. When the quantity of iron sulphate required to cure the trouble is so small as the one shown above (0·0001%), what is contained as an impurity in zinc sulphate is more than enough to be effective, and it appears to be a fallacy to think that the zinc sulphate is the real curative agent in all cases. Spraying of iron sulphate alone has also been found to be very effective against mottle leaf of *Mosambi* and Navel Orange trees in Baroda, although the effect is seen several months after spraying is done. Since spraying iron sulphate reduces the cost very considerably as compared with spraying zinc sulphate, the former is very strongly recommended to be tried first. In the Gujerat area, this trouble is rather common in citrus orchards, and it is suggested that spraying of iron sulphate once or even twice in the year as a regular cultural operation be adopted both to cure and to prevent the mottle leaf trouble. Spraying should be done in fair weather, when the sticking material may not be washed away by rains for some days at least.

In the Madras Presidency, spraying of mottled trees with a mixture containing 10 lb. zinc sulphate, 5 lb. hydrated lime with or without ½ lb. spreader like lime casein or skimmed milk, in 100 gallons of water has proved very efficacious in

bearing plantations. The disease usually disappears a few days after spraying, and beneficial effects last for at least one season and possibly for longer periods. It has been suggested that even trees not affected by mottle leaf are benefited from this spray (164). The spray should be applied preferably when the tree is not making active growth, since the young foliage and very small fruits are liable to be affected. It was, however, seen that even when spraying was done on flowers in the stage of opening or setting fruits, it caused no significant damage in a *Mosambi* orchard in the Baroda area. This trial is, however, not conclusive. When mottling is caused by water-logging, excessive salinity in the soil or defective culture, zinc treatment is not expected to be of much use.

Along with spraying of iron or zinc sulphate the trees sprayed should receive as good cultural and manurial treatments as possible in overcoming the trouble. Choudhury (54) working in the Punjab records: "Chlorosis of Malta (*Citrus sinensis*) has been investigated. Chlorotic areas become slightly more acidic than the adjoining green portions. No correlation with the soil conditions has been found. In transverse sections, the chlorotic areas show light green chloro-plastids and in bad cases, where the regions turn yellow or whitish, breakdown of the granules is seen and also the plastids degenerate and the cells become empty and collapse. Injections and sprayings with different iron salts have been tried for curing chlorotic conditions. Ferrous sulphate in 0·00015% solutions, whether injected or sprayed, has been found to be most efficacious and as spraying requires no special skill this method has been recommended."

In the Nilgiris District, Coorg, and Wynaad of Malabar, a fruit and leaf fall of orange trees is very common. An attacked tree gives a fœtid odour and can be detected from a distance. This usually starts with the onset of the monsoon and does maximum damage in August and September. It is caused by the fungus *Phytophthora palmivora* Butler.

Leaf and fruit fall of orange trees

The first symptoms on the leaves and fruit are water soaked areas which gradually rot more. They are later shed in large numbers. It is usual to see large numbers of shed unripe fruits under an attacked tree.

In Coorg the disease is controlled by spraying with Bordeaux

mixture, once at about the time monsoon sets in and again in October. Such timely spraying completely controls the disease.

Cracking of fruits

Cracking is noticed in limes and lemons, more than in *Santras* and *Mosambis*. Cracking is the effect of irregular physiological changes in the plant tissues caused by irregular watering and manuring. Considerable damage is caused to the crop by this trouble, but its severity is limited.

Tambera

Fruits of the *Mosambi* in plantations which are over-irrigated or which remain moist all the year round, are seen to be covered with a deep brown coating. The rind is unaffected inside, and the fruit is also quite good. Its appearance is, however, completely spoiled and this fact lowers the market value of the fruit. The cause of this trouble is the attack of mites. Spraying with lime sulphur wash reduces its seriousness. Preventive measures may be adopted by draining the soil of the plantation and by regulating irrigation water.

Fruit sucking moth

One of the most serious pests on orange fruits in Peninsular India, is the fruit sucking moth, which punctures and sucks the juice of almost ripe fruits. The fruit then drops after two or three days. There are several species of this insect, of which *Ophideres fullonica* L. is quite common. It is a stout moth with upper wings of greyish colour and the lower ones conspicuously bright orange and black. These are *nocturnal* in habit, and therefore remain hiding during the day and start feeding at dusk. In the Madras Presidency, bagging of young fruits with envelopes of palmyra leaves is almost universally practised as a prevention against their attack. This is quite economical. Even paper bags may be used for this purpose. The moths can also be hand-picked and destroyed at night with the help of torches and this mechanical method of control is quite effective.

Stem borer

Arbela tetraonis M. bores in the stem of orange and lemon trees, mostly in old and neglected gardens. Besides these, it also feeds on several other fruit trees namely guava, pomegranate, mango, etc. The larva throws out peculiar patches of excreta on the bark of the trees near the hole made by the borer inside. At night it comes out and feeds on the bark. The galleries which the

larva bores and the freshly eaten bark are the symptoms of attack. By way of control (i) syringing the burrow with a little chloroform or creosote and plugging it, and (ii) painting the bark with paris green solution of one ounce in two gallons of water after removing the excreta and the silky material from the trunks are very effective. Two applications in a week are enough to check the pest.

Aphids *Toxoptera aurantii* Boy

The green fly attacks all kinds of citrus plants practically throughout the year. Both adults and nymphs feed on the sap and growing shoots and check their growth. Such plants usually impart unhealthy appearance with lower leaves looking oily, and sticky due to "honey dew" secreted by the insects. Blackening of leaves due to mould may also be conspicuous.

The incidence of attack is particularly serious during the months of October to February. In nature aphids are kept in check by a small lady-bird beetle, red or yellow in colour with black spots, as the adults as well as their grubs feed actively on them. Spraying with fish oil rosin soap (½ lb. in four gallons of water) or nicotine sulphate (1: 800) is a very effective control.

White flies

Dialeurodes citri A. is a major pest. Black nymphs are seen feeding on the underside of the leaves. "Honey dew" secreted by the pest develops a sooty mould which interferes with the photosynthesis. The pest is active from October to February and can be controlled by spraying with rosin compound in the ratio of 1: 6 or fish oil rosin soap (1 lb. in 4 gallons of water).

The lemon caterpillar

The caterpillar *Papilio demoleus* L. attacks all kinds of citrus plants and *kagdi* limbu, particularly. The butterfly is large and conspicuously coloured and is common throughout the plains. It lays small round yellow eggs singly on the top-most shoots and the young caterpillars feed on tender leaves. Their colour changes from brown with white markings, to vivid green with lateral brown markings when full grown. The caterpillar pupates on the plant, fixing itself by the tail and by a thread round the body. It also lays eggs on Bel (*Aegle marmelos*) and some other wild plants. There are several broods in a year. By way of control, hand-picking and

with lead arsenate are effective. The operations, should be repeated at intervals.

Chrysonphalus aonidum Rilay is also a major pest attacking leaves and fruits in the Bombay Presidency. The scale is small, round and brownish black in colour, which spoils the appearance of the infested fruits. It, however, only sticks to the fruits superficially and can be rubbed off with a rough piece of cloth before the fruit is packed for marketing. The plants should be sprayed with fish-oil rosin soap at the rate of 1 lb. in 4 gallons of water.

Scale insect

Phyllocnistis citrella S. produces glossy mines specially on young leaves. The affected leaves are disfigured with a number of irregular, unsightly and glistening patches on them and a number of zigzag mines are prominent. The damage caused by this insect is not severe, and is confined to the affected leaves only although in the case of virulent attacks, the plant may suffer from the serious dimunition of the healthy leaf area, and consequently of the elaborated food substances. It is also believed by some that the insect is a carrier of canker infection and, therefore, its successful control is essential for preventing the more serious canker incidence at least to some extent. Removal and destruction of the affected leaves and spraying of nicotine sulphate (1: 800) or of strong tobacco decoction, are effective control measures.

Leaf miner

Manganese deficiency is widespread in orange areas. Severe deficiency symptoms were in some areas associated with early decline of lemon trees. Sprays including manganese sulphate and soda ash 10-5-100 and 4-2-100 respectively, proved successful in some cases. In others when followed by fumigation, they showed signs of young leaves burning (214).

Mineral deficiency

As soon as slight mottling appears, a foliage spray of 4 lb. of zinc sulphate plus 2 lb. of hydrated lime in 100 gallons of water is recommended to be applied in most places and used regularly once a year. In extreme cases, 4-6 gallons of spray containing 10 lbs. zinc sulphate and 5 lbs. lime in 100 gallons of water is recommended (243).

Abnormal drops of flowers or fruits are observed in some orange groves in certain seasons. Such drops may be caused

by one or more insect pests, or fungoid diseases, weak health of the trees, insufficient supply of nitrogen or moisture in the soil, high wind velocity, and low temperatures or sudden variations in weather conditions. Excessive stagnation of water and deep ploughing or other tillage practices that cause disturbance to the roots at the blooming or early fruit setting period may also cause enormous fruit and flower drops. In every grove, some amount of flowers and fruits are bound to drop even under normal conditions and "June-drop" is the term applied to the heavy dropping period which is characteristic in American citrus orchards. The grower should be able to distinguish the unusual from the normal drop, and adopt suitable cultural practices or undertake control measures after studying the causes operating in each case, preferably in consultation with the workers on fruit culture or fruit diseases and pests.

Fruit or flower drops

Reductions in fruit drop from 27% to 96% are reported by using 2, 4-D water sprays at concentrations of 5 p.p.m. to 25 p.p.m. of the free acid equivalent (245).

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CHAPTER IV

GUAVA

(*Psidium Guajava* L.)

One of the hardiest of fruit trees, the guava is grown extensively in India. It is essentially a tropical tree, and adapts itself to most conditions of soil and climate prevailing in India.

Introduction

The cultivation of guava seems to be fairly old in this country. Total acreage under guava in India is 1,05,155 distributed as follows:—

Name of Province	*Area in acres*
United Provinces	58,454
Bihar	19,992
Central Province	10,023
Bombay	7,415
Orissa	6,000
Madras	2,500
Hyderabad	771

The original home of guava is said to be the tropical parts of America. The Spaniards found this fruit tree growing in extensive regions from Columbia to Peru, when they first visited the American continent. It is, however, found difficult to point out a more restricted area as the original home of guava because of its spread due to natural agencies, as for example, birds in very early times. It is reported that the distribution of this fruit tree to other countries of the world is due to the Spaniards.

The guava tree is at present found cultivated in most of the tropical countries of the world. In the Fiji Islands, this fruit tree is considered to be an "obnoxious weed" and the Government of that country is endeavouring to eradicate it. Guava is grown in California, Florida, Cuba, Brazil, Mexico and Peru, and has been naturalised in the Hawaii Islands. Stray trees are also found on the Mediterranean coast of France and Algeria. It is a common fruit tree in Southern China and the Malayan Peninsula. In India, guava trees are cultivated with care in

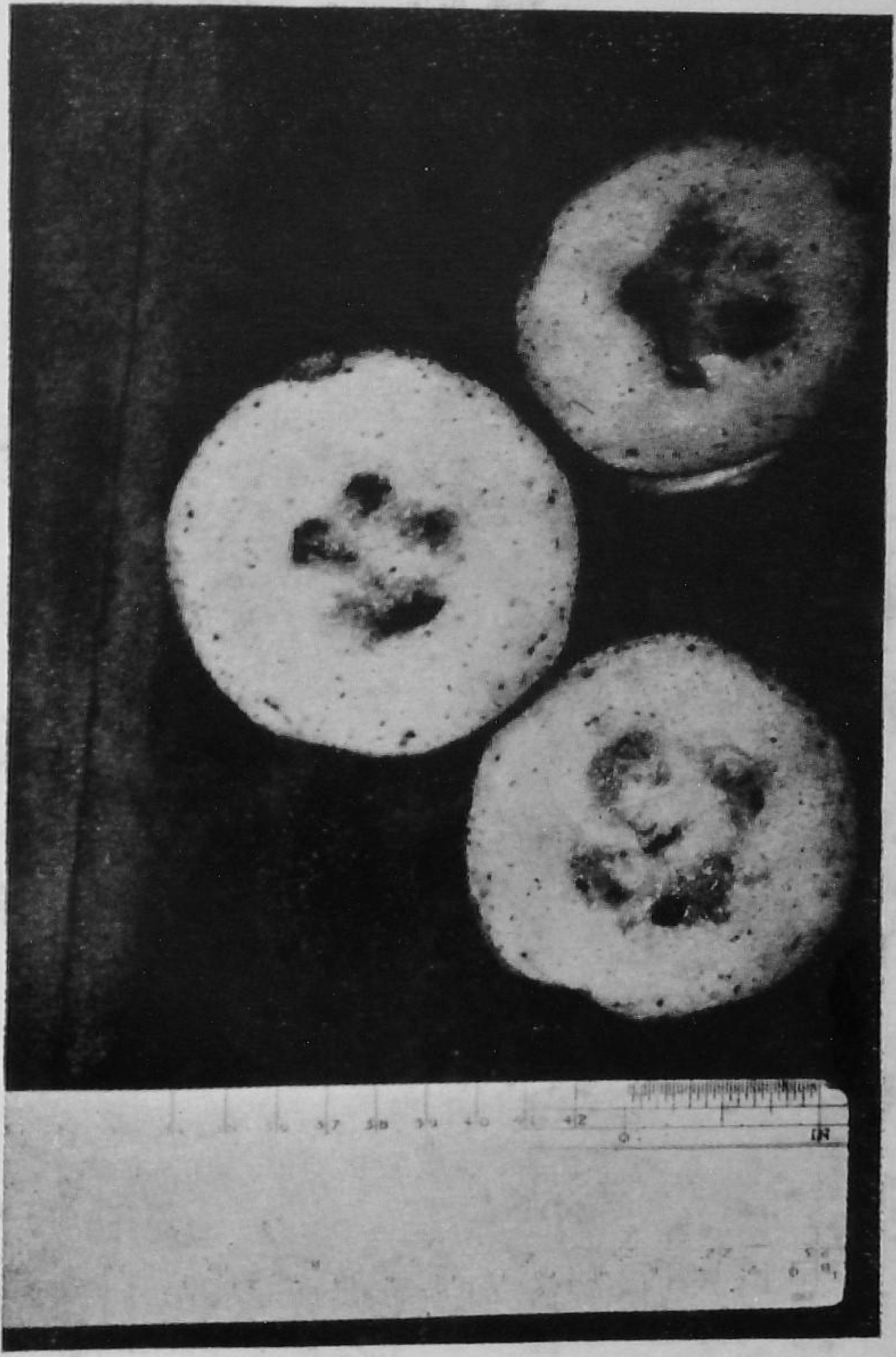
many provinces. Guavas from Lucknow, Allahabad, and Banaras are reputed for their size and quality all over India (20). The odour which the guava fruits possess is not considered pleasant by some people. But for this and for the hard seed contained in many varieties, the guava would have become one of the most popular fruits. With the progress of the canning and by-product industries, however, the guava holds out bright promise as one of the remunerative fruit crops all over India.

Varieties

The main varieties of guava are ordinarily supposed to be two, namely, the white and the pink fleshed. The former is more popular and more extensively cultivated and has several strains showing minor differences. Popenoe (25) describes the following species:—

1. *Psidium guianense*, a white fleshed fruit deriving the alternative specific name from its origin in Guinea in Africa.
2. *P. cattleianum*, or the small strawberry guava which is perhaps the wild ancestor of cultivated forms. Variety *lucidum* has sulphur yellow fruits.
3. *P. chinense*, which is an unindentified horticultural variety.
4. *P. friedrichsthalianum* is the Costa Rican guava with sulphur yellow fruits and with white flesh.
5. *P. guajava*, is the more common cultivated group, with white, yellow or pink flesh.

The varieties grown in India mainly seem to fall under the last species, namely, *Psidium guajava*. The fruits are principally of two shapes, the pyriform and the pomeform. The varietal names in this country are mainly derived from the places they come from, and it is nearly always that a local name stands for a distinct variety. The considerable variations found in these fruits are due to the fact that guava plants are generally raised from seeds. The *Cattleianum* and Chinese guavas are cultivated on a limited scale in some parts of India, but these are as yet of no commercial importance. A bushy variety commonly known as hill guava or wild guava, is found growing extensively on the uncultivated hill slopes of the Nilgiris and some parts of the



THE SEEDLESS GUAVA FRUITS. THE LOCULI AND THEIR UNDEVELOPED OVALES MAY BE NOTED.

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lower Himalayan regions. This has not attracted much attention so far except as an inferior substitute in salad and for the preparation of guava jelly.

The principal three forms of cultivated guava obtained in the Bombay Presidency are the following:—

I. These are usually large in size, mellow and delicious and have a few soft seeds. Fruits weighing as much as a pound each may be found in this group. The Sind, Lucknow, Allahabad, Banarasi and Dholka types fall into this group.

(1) *Sind.* Trees bushy and of spreading habit; fruit has few and soft seeds; elliptic round in shape; normal number of loculi is reduced and filled with white or reddish pulp. Quality of fruit very high.

(2) *Lucknow.* Tree bushy in growth, and the fruit is long or occasionally long with ridges on the surface. Seeds are few and soft. Pulp slightly acidic even when fruit is fully mature.

(3) *Dholka.* Tree is vigorous in growth and the fruit is fairly big; seeds are few and soft.

II. These types are hardier and more seeded than the above. They include the Nasik, Dharwar, Miraj and Limbgaon varieties.

(1) *Nasik.* The tree is erect in habit and bears bottle shaped fruits, with distinct long neck. The fruit has a rough skin and keeps well.

(2) *Dharwar.* The tree is bushy with elliptical hard fruits, which taper towards the stalk end. Seeds are many. Fruit keeps well. This is the type of fruit grown all over the Deccan and Karnatak, at Limbgaon and Miraj, as well as at other places. Each tract claims its product as superior in quality with little attempt for justification.

III. Stray plants of *Psidium cattleianum* as well as another cultivated type, which has practically no seeds in it, are often found in the Bombay Presidency. The seedless type is lately being propagated vegetatively on a large scale, and distributed for large scale planting.

It would appear that the northern types are generally of better quality, although the southern types keep well for a few days longer, which is no small consideration in marketing so perishable a fruit as the guava. In the United Provinces, a number of distinct guava varieties, such as *Hafsi* and *Karella*, are popularly recognised. But the distinction between these varieties has yet to be defined.

Soil

The guava tree grows well in sandy and alluvial soils, which have an admixture of clay in them as in parts of Sind. The black and light *goradu* soils of Gujerat are also suited for it as well as the fertile alluvial deposits of river banks. In the Deccan, guava plantations are seen in deep black, medium black and ill-drained soils, although the lighter and better drained soils are highly congenial to them. The banks of the Krishna, the Bhima and the Godavari rivers have large guava plantations along them. The black, red and brown loamy soils of the Karnatak including the stony shallow soils near Dharwar have all got thriving plantations of this fruit tree.

Climate

The guava tree grows and fruits well in places of extremes of climate as in Sind, where the maximum temperature during summer rises up to 114°F, and the minimum falls to 40°F during the winter. The annual rainfall is hardly over seven inches. In the Gujerat, where the range of temperature is narrower (50°F to 112°F) and where the average annual rainfall is more (29 inches) than in Sind, guava fruits of very high quality are produced. In the Deccan and the Karnatak districts, where the temperature ranges are still narrower, and where the monsoon is stronger, the guava plantations do thrive equally well. On the slopes of the Western Ghats where the rainfall is very heavy, stray trees of guava are seen growing and bearing irregularly. Being a tropical tree, the guava plant can be grown almost in any part of this country. It thrives

GUAVA TREE OF LUCKNOW 49 STRAIN.

The tree has a spreading habit. In the foreground seedling stocks in pots are shown grafted to the tree.

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better and produces quality fruits, when grown in places of extremes of climate than in those of equable climate. This hardy tree is not much affected by cold waves, which occasionally sweep over the Deccan and Gujerat tracts.

Propagation

Guava plants are propagated generally by seeds in the Bombay Presidency. However, certain trials conducted at the Ganeshkhind Fruit Experiment Station, Kirkee, have shown that seed propagation gives rise to considerable variation in the form and size of fruits, the nature and flavour of pulp, seediness, and other morphological characters such as the spreading or erect growth habits of trees. Guava plants are, therefore, propagated lately by grafting, (enarching being the most common method adopted) in the progressive nurseries of this country. Budding is also found possible in guavas. But this method is not yet widely adopted. It is noticed that layers and gooties prepared on fairly mature stems also strike roots and produce good plants. It is also possible to propagate from root cuttings or suckers which spring from the roots. Stem cuttings are not very successful.

For grafting, rootstocks are raised by sowing seeds in raised seedbeds at the commencement of rains. Guava seeds are found to keep well for a year or more, without their power of germination being much affected. Seeds are obtained from ordinary fruits which ripen on the trees. They are cleanly washed and dried in shade, and mixed with fine wood ash. On drying, the seeds are stored in properly closed tin boxes and preserved in a cool place until they are required for use. Seedlings are transplanted in pots when they are about six inches tall. The weaker seedlings are rejected and the more vigorous ones are alone selected for potting. This selection gives a good start to the seedlings and they turn out to be good rootstock plants. The pots are prepared in the usual way with a layer of pot shreds on the bottom hole and a layer of well-made compost over it. The compost may be similar to that mentioned under mango. Transplanting can be done at any time under orchard conditions, but the plants require to be placed in shade and watered judiciously until they establish in the pots. The soil in the pots has to be stirred at least once a month, and some kind of liquid manure added to it after each stirring. The side shoots have to be pruned as soon as they appear, in order to obtain a strong

straight rootstock to graft upon. Guava plants can be got ready in this way in about a year from sowing.

Enarching is the common method of grafting followed, and it is best done during monsoon, when there is a slight break of rains. The plants are then in sap-flowing condition and grafts "take" readily. The scion should not be separated for at least three months from the time of grafting to ensure successful union. When the scion is separated from the parent plant, the graft is kept in shade for some days to harden. If the scion withers in a few days, the graft is not successful, and the rootstock may be used again for regrafting. If it does not, then the rootstock is headed off above the graft-joint. The graft is then ready for sale, but it is preferable to harden it for about three months before planting it out in the open field.

In Ceylon (23), the guava is propagated by gooty and by layering. In the Malayan Peninsula this tree is generally propagated by seeds.

A method of propagating guava very rapidly and with little trouble is to use suckers which may be forced to appear, if desired. Lateral roots are exposed about two to three feet away from the main trunks of the trees and cut wounds are made on them. In course of time, these roots throw out suckers from their dormant buds. When the suckers grow to a suitable size, they may be severed from the mother tree together with a portion of the roots and transplanted in their permanent place. This practice is not, however, much in vogue. Du Preez (8) suggests that guavas should be propagated by layers, root cuttings, hardwood cuttings or suckers, as the seedling progeny even from a single selected fruit is very heterogenous.

Budding as a method of propagation has not shown promise in South Africa though it succeeds well in Florida, California and Java (8). A few attempts made to bud upon well-grown rootstock plants at the Ganeshkind Fruit Experiment Station, Kirkee, met with considerable success. The method adopted was the shield budding.

Planting

The land in which guava plants are to be grown, is prepared by clearing all brushwood growth, ploughing and harrowing several times. It is properly levelled and green-manured by growing sann hemp (*Crotolaria juncea*) in the previous season. Pits are then dug in

the land at required distances during the hot weather and left open to the sun and wind for a few months. Pits are generally taken fifteen feet apart except in the Gujerat tract where the plants are spaced at twenty feet apart. Pits may be of two feet by two feet by two feet, or they may be three feet cube. The soil of the top half of the pit is kept separately from that of the bottom half, with the belief that the latter is properly weathered by the time it is required to fill the pit. Any kind of brushwood material may be burnt in each pit to improve the texture of the lower layer of the soil. Before the rains start, the pits are filled with the original soil, mixed with about fifty pounds of old and well rotten cattle manure. While filling the pit, the top soil is placed at the bottom and the bottom soil is filled on it. In fertile soils, additional manure is not necessary while planting. As soon as rains commence, planting is done by using seedlings or grafts as desired. Grafts of superior varieties are to be preferred to seedlings, as the latter cannot be depended upon to produce quality fruits. While planting, it is advisable to prune the tender shoots of the plants, as otherwise they may dry up on account of the shock which the young plants receive when the roots are disturbed. In the Dholka (Ahmedabad) tract four or five seedling plants are planted in each pit, but this is not recommended as the plants get crowded in no time. If grafts are planted, the graft-joint should always be kept sufficiently above the ground level. Watering follows planting immediately, unless it rains, and is copious in the beginning.

Irrigation

The guava is a very hardy tree adjusting its water requirements remarkably to the hot and dry conditions prevailing in the Deccan tract. The chief economic consideration which encourages growers to go in for guava cultivation is that, this tree does not suffer much if it is not watered during the hot months, when wells usually go dry. It is, however, found that where the plantation receives better care and more irrigation, the yield of fruits is heavier and the fruits are of higher quality than where the trees are neglected in the drier part of the year, as it usually happens. Irrigation ought to be given copiously on planting. Then it follows as required once in ten days or so, except when it rains. It is continued throughout the year for the first three or four years, according to the availability of water during the hot weather. After

the tree begins to bear as it does in its third or fourth year, irrigation is given only during the bearing period. Guava plants bear flowers soon after the rains start in June, and the fruit is harvested by January in the following year. From February to June following, the trees are practically left to themselves.

There are two systems of irrigation in vogue in guava plantations, namely, the ring or the basin and the bed or check systems. Irrigation in furrows is rarely adopted. In the ring system, a low mound of earth is raised at the base of the trees and water is given in a shallow trench round this mound, so that the irrigation water is prevented from touching the trunk of the trees directly as was explained already under citrus fruits. Moreover, this system can be adopted to irrigate trees exactly where the feeding roots lie, increasing the spread of the mound as the trees grow in size. This system also economises the quantity of water required for irrigation. The bed system consists of irrigating trees in circular beds at the base of trees, in which case the trunk comes into direct contact with irrigation water. As the whole bed is filled with water at each turn of irrigation, this system consumes more water also. Although the usual practice is to irrigate in beds, the ring or the sloping basin system is found to be more suitable. As a result of trials conducted at the Ganeshkhind Fruit Experiment Station, Kirkee, it is found that guava trees can do well with seven to ten irrigations per year, consuming thereby fourteen to twenty acre-inches of water in addition to the annual natural precipitation which comes to about twenty inches only.

Manuring

Manuring is one of the most important operations in the cultivation of guava trees as it is in all fruit trees. Farmyard or cattle manure is the most common manure used in the Bombay Presidency, although in some tracts an additional dose of other manures is also given. For example, wood ash is used in seed beds in Baroda and Poona with a view to raise good seedlings. Tank silt is applied in Dholka and sheep dung is sometimes used in the Karnatak. Seedlings grow to about two feet high in the course of a year and become fit for transplanting in the field if these manures are applied. At the time of transplanting of guava plants some manure is usually given. In the Baroda territory, a small quantity of common salt is added to each pit along with about four ounces of castor cake. These manures are meant to counteract

GUAVA SHOOTS IN FULL BLOOM. FLOWERS ARE BORNE ON NEW SPURS.

Facing page 253.

the white ant trouble which is so common in the Gujerat area. The use of three to four pounds of castor cake and about forty pounds of cattle manure per bearing tree per annum is found to give very good results in Karnatak. After the trees are planted in the field, they receive no manure during the earlier stages of growth, when inter-crops are raised between the rows of the main crop. The plants are regularly weeded, manured and irrigated along with the inter-crops. When the trees are treated for the crop (*bahar*) the above dose of manure is given and the roots are covered up. Guava trees readily respond to the care they receive and yield accordingly.

Inter-crops

Guava trees, it has already been stated, are planted fifteen to twenty feet apart each way. This leaves some open space in which other short-lived crops may be taken during the first few years of the plantation until the main trees spread out sufficiently to occupy the whole area. Inter-crops usually consist of some seasonal vegetables or other agricultural crops such as *guvar* (*Cyamopsis psoralioides*), *bhendi* (*Hibiscus esculentus*), onion (*Allium cepa*), turmeric (*Curcuma longa*), etc. In the red soils of the Dharwar district, dry crops of legumes and millets are also grown. At Limbgaon in the Satara district, turmeric, onion, garlic (*Allium sativum*) and such other vegetables are grown during the monsoon. In the Poona district, where vegetables command a good and ready market, various leaf and fruit vegetables are grown. In the Gujerat tract, lady-finger (*Hibiscus esculentus*), brinjal (*Solanum melongena*), chilli (*Capsicum* sp.), ginger (*Zingiber officinale*), cabbages, knolkohl and other vegetables are taken.

Treatment for *bahar*

Bahar or the production of blossom generally occurs when the trees put forth new shoots at the beginning of a new growing season. The existence of three distinct growing seasons in the Deccan and the peculiar phenomenon of some trees producing blossom thrice a year has already been pointed out under citrus fruits. Guavas also respond to the various practices like withholding irrigation water, and exposing feeding roots and pruning the fibrous ones, that are applied in the Bombay Presidency to force out blossoms in any of these three seasons. Guava trees come to bearing in the third or fourth year of planting. They can then be treated for bearing a regular crop. The treatment is generally

given to induce blossoms in the *Mrig bahar* (June-July), the chief idea underlying this treatment as was pointed out in the case of citrus trees, being to check vegetative growth of the trees and to induce fruiting. Since the guava trees have a tendency to produce blossom at every change of the season, as explained above, they may produce some blossom three times a year under natural conditions. In order, however, to concentrate the crop, in one season, the trees are artificially rested for any one of the three flowering seasons. The October flowering is, however, difficult to treat for, owing to the preceding rainy months, when it is impossible to withhold irrigation water for resting the trees. This *bahar*, locally called the *Hatti bahar*, is, therefore, mostly missed. The third *bahar*, namely, *Ambe bahar*, or January-February flowering is also not popular, as this requires the trees to be irrigated during the hot months, when wells go dry, and as the fruit is harvested during the rains when they have little demand in the market. The hot season during which water is usually withheld, induces the plants to "dry" up and shed most of their leaves. Before the rains, the orchard is ploughed and cross-ploughed, and cleaned of all the dry and dead branches on the trees. The trees are also examined and treated for stem borers, or other insect or fungoid trouble. If simple withholding of irrigation water does not sufficiently check vegetative growth of the trees, as it happens in some deep black retentive soils, the roots of the trees are exposed to make the treatment more severe and effective.

Root exposure in the case of guava trees consists of opening out the soil at the base of the trees in a circle within a radius of about three or four feet from the trunk, and to a depth of about eight to ten inches. Removing the soil in this way exposes the feeding fibrous roots as well as some of the conducting ones. The smaller and injured roots are neatly pruned and any severe wounds caused to them in digging the soil are trimmed and the cut ends are smeared with coal tar to help healing and to prevent infection of harmful soil organisms. The roots are left exposed for about a fortnight or more if required, until the trees shed some of their leaves or show sufficient signs of wilting. When roots are exposed the annual dose of manure is added to the soil, which is opened out and at the end of the period of exposure, the soil mixed with manure is replaced

in its former place. Irrigation beds and water channels are prepared and watering commences on about the tenth of June. The first few turns of irrigation are sparing, as in citrus lest the new flush becomes vegetative growth, suppressing the appearance of blossom. After the third irrigation turn, normal water once in ten days or so is resumed, unless it rains during that period. Irrigation continues till the end of the harvesting of the whole crop, that is, up to February. The usual practice in adult plantations in the Deccan is to leave the guava orchard to itself without doing any operations in it from February until the end of April or thereabout, when treatment for *bahar* again begins.

Bending

During the resting period cultivators resort to bending the branches of guava trees, with a view to check the upward flow of sap and in order to stimulate dormant buds on thicker stems to produce blossoming buds. "Bending" consists of tying together branches of adjacent trees in a horizontal position. This operation is practised in alternate years. Branches of guava are naturally flexible and spread out freely if left to themselves. By bending the middle parts, the branches are strained and dormant buds on the thicker parts especially get stimulated to growth activity. Such sprouts bear flowers and produce fruits.

The system of bending branches as a means of forcing guava trees to fruiting, as explained above, is not economical under the present conditions of cultivation, as it involves considerable extra labour and hinders free inter-tillage. The branches might also break in the attempt to bend them. When repeated several times, the bending treatment leaves the trees with a number of decaying stumps of broken branches which admit infection of insect and fungus troubles. The plantation gets crowded up in no time, hindering all operations of cultivation and even free movement in the orchard.

Pruning

In order to avoid this condition of bent-tree plantations, the Department of Agriculture, Bombay, undertook investigations to ascertain if a suitable method of pruning can be substituted for the practice of bending. The method of pruning found most useful was to cut off the previous season's growth leaving only a couple of buds on it at the base. The pruned branch, in other words, would be left with a stump of about three inches in length carrying two or three buds on it.

As the top is no more able to utilise the sap sent to these stumps, the buds which were till now semi-dormant, are stimulated and they put forth new sprouts. The new sprouts produce blossom and the new season's crop. Pruning for fruit spurs is best done in the month of May when the trees are resting, and before the rains set in. Irrigation is given two or three weeks after pruning when the buds start growth, to bear flowers in about a month. If rains are late and irrigation water is scarce, the natural growth is scanty and flowering is retarded. The results obtained did not show any considerable increase in the quantity of fruits borne, as a result of pruning. The investigations were further followed up during 1921-1924. Individual tree performance was recorded. The comparative study of the yield records of six hundred pruned and unpruned guava seedling trees showed that the total number of fruits per pruned tree is only half of that of the unpruned trees, but the size and the quality of the former were much improved. The fruits on pruned trees, therefore, commanded a higher market price. Pruning has other advantages in that, bearing of the plants is hastened in the season resulting in early harvesting. The pruned trees are seen to flower earlier than unpruned ones under uniform cultural treatments. Pruning also gives protection to fruit against bats, birds, etc., by affording good shelter to the fruits hiding them from the sight of birds by the vigorous leafy growth of trees. The growers' method in the Poona and Satara districts to bend and tie together the outgoing lateral branches of neighbouring trees in order to stimulate dormant buds on these branches to sprout, neither lends any shape to the trees nor restricts the growing size of the trees to any extent.

In a trial at Allahabad, guava trees planted 25 feet apart were pruned lightly; others at 15 feet apart were pruned heavily. The heavily pruned trees produced larger fruits, but the number of fruits per tree was so low that the yield per acre was less than half of that of the lightly pruned trees. The heavy pruning thus proved entirely uneconomical (16).

Training

Guava trees are sometimes trained to shape. Training may consist of cutting off dead and dry branches and of nipping off the suckers. The shoots in the interior which would crowd the "head" of the trees may also be removed in order to get an open-headed plant. Guava

trees lend themselves to training easily. Their shoots have a large number of buds, and flowers are borne in very definite positions on the current season's growth. Long branches are thrown out generally if trees are left to themselves. With a view to induce more new shoots which would bear flowers by exposing mature stems fully to light and air, the espalier system was tried in comparison with the untrained tree. Each plant was made to carry only three lateral branches by nipping other side growths. These branches were taken at a height of 2½, 4 and 5½ feet respectively from the ground level. They were tied horizontally to thin wires fixed to posts planted at regular distances as in a fence. The tender guava branches bend well, and can be conveniently tied to the wires fixed at any required height. When they mature and grow in size, they keep up the horizontal position permanently and do not need further support of the wires. These main branches are termed "horizontal laterals". Vertical branches are induced to grow on these horizontal laterals till they meet the higher laterals, with the result that the whole structure looks like a net-work screen. Fruiting spurs are encouraged to grow on all these branches by keeping spurs in check. They are pruned annually leaving a few basal buds as mentioned previously. Plants in a row are allowed to throw out laterals only sideways along the rows, and the ends of such laterals often meet.

As a result of observations over several years, it is found that the above system of training guava plants does not ensure adequate bearing of the trees. Pruning the annual growth is found essential to encourage fruiting spurs and several bad knots are formed on the trees, encouraging borers and birds to feed on them. This system is, however, very suitable to small compounds of residential buildings where a few guava trees can be grown by the side of walls or where they can be trained to divide different sections of the garden without themselves occupying much space. In such cases, the trees would bear a small crop of fruits annually, which will be appreciated by the owner for home consumption.

At Kodur, on the other hand, it was observed that the trellis trained guavas have certain desirable features which entitles this method for a much greater popularity than it enjoys at present. Untrained guava trees become unthrifty under average soil and

care, and pruning of shoots is neither done nor is feasible on large trees which have been allowed to grow to an irregular shape. When trained on trellis, annual pruning is done both to maintain shape and to produce a succession of fruit bearing shoots. Till about the tenth year, such guavas have been found therefore to possess a more thrifty performance than untrained guavas.

Improvement of guava

As guavas are commonly raised by seed in the Bombay Presidency, they have resulted as already stated, in very inferior types of trees bearing crops of low grade fruits. This brought up the question of improving them with a view to evolve a strain or strains of guava which would have soft but few seeds, large quantity of edible pulp, pleasant flavour, good yield, and medium size, with an attractive appearance for the market. Investigations with this end in view were undertaken at the Ganeshkhind Fruit Experiment Station, Kirkee, in an orchard having 600 guava seedling trees. These seedlings were planted in four plots and were all almost 14 years old, when observations regarding their individual performances were recorded. Great care was taken to maintain uniformity in cultural operations. The fruits of each tree were harvested separately, graded, counted and weighed. As a result of these observations, guava seedlings have been found to exhibit a large number of variations. Variation in the seed content of the fruits of individual seedlings is specially marked. Instances of bud variation are also not rare. Guava trees have thrown out variegated growths which have been vegetatively propagated as such and are being grown as ornamental plants.

Rolf (27), however, mentions that guava comes fairly true to seed so far as the general qualities of the class go. But experience in the Bombay Presidency does not support this view. Seedlings vary widely both in fruit quality and yield. Observations recorded at the Ganeshkind Fruit Experiment Station, Kirkee, based on the studies of individual seedling guava trees help to classify the trees under three main heads, namely, constantly high-bearing trees; irregularly bearing trees; and constantly shy-bearing trees. On the basis of records of productivity of individual trees as well as other qualitative characters as mentioned above, several high-yielding strains of good quality of guava have now been isolated. They are being propagated

vegetatively to prevent the quality of fruits borne by the progeny from deterioration. Out of these selections, the strain, named Lucknow 49, has stood further trials in the field on a fairly large scale for its high productivity and superb quality.

Brief descriptions of some of the selected strains are as follows :—

Nasik No. 88. Trees of medium size, with open habit of growth. Bark of stem smooth and ashy grey; leaves elliptical lanceolate and slightly folding at night; fruit pear-shaped or pyriform, colour golden yellow when fully ripe; seeds few but hard; pulp sweet but slightly acidic.

Lucknow No. 49. Ascendant shrub with flattened top and vigorous habit of growth; leaves elliptical lanceolate; fruit large and spherical in shape; fruit colour bright yellow when fully ripe; pulp milky white, sweet and of agreeable flavour; superior quality of fruit but of poor keeping quality.

Lucknow No. 46. Small sized tree among the Lucknow group; low habit of growth; bark ashy grey with greenish patches; leaves elliptical lanceolate of large size; fruit of medium size, but oval or bottle-shaped, skin smooth and yellow; pulp very delicious with very few soft seeds.

Lucknow No. 24. Plant is medium-sized with an open habit of growth; leaves lanceolate and half-folded, light green and longer than those of the other Lucknow types; fruits ovate with narrow furrows on the surface; when fully ripe, colour is yellowish with a tinge of rose; seeds few and soft; pulp is rather insipid in taste but is not disagreeable.

Dharwar No. 34. The tree is compact and cylindrical in appearance with erect branches; leaves elliptical lanceolate, and half-folding, fruit medium sized with sprinkling of red when ripe; seeds hard and many; pulp is sweet.

Sind No. 63. A medium-sized tree with a smooth and dark brown bark; leaves elliptical lanceolate, light green

in colour, and with folding habit; fruit develops yellowish-green colour when ripe; seeds few and soft; pulp milky white and thick; tastes well.

Kothrud No. 19. Medium-sized tree with an open and erect habit; leaves lanceolate; fruit large in size, pear-shaped, with a narrow neck and rough surface; colour of fruit white when ripe; seeds are many but soft; pulp acidic sweet.

Dholka No. 7. Tree of vigorous habit; fruit is big with soft and few seeds; pulp slightly acidic, with sweet and good flavour.

These selections have all been propagated vegetatively and planted out at the Fruit Experiment Station, Kirkee, and are now under field trial. Lucknow No. 49 has already become popular for planting in orchards.

Yield of guava trees

The yield of trees varies according to the nature of plants and cultural practices adopted. The money value of yield further depends upon market conditions and on the situation of the plantation.

Life of guava plantation

In the Dholka tract (6), guava trees are almost continuously irrigated, sometimes even when the trees are resting. The maximum period of stoppage of water to them in this tract is a month, when the trees rest. It is found that perhaps due to over-irrigation, guava trees in the Dholka area do not live long. For about twelve years they bear well, and degenerate after that age. The water is given here about twelve times in the year in addition to what is received through rains. Guava trees of fifty years or more in age are seen near Ahmedabad. Some plantations in the Deccan are very old too, perhaps older than in Ahmedabad.

Rejuvenation of old guava plantations is achieved in the Khandesh districts, especially near Dhulia, by heading the trees back almost to the base of the trunk. The low stumps thus left, produce vigorous growth and a fair head is formed again in about two years from pruning. Gradually, these new shoots begin to bear fruit, and often they may yield about 200 to 300 saleable fruits per tree.

Guava fruits come to harvest in November, and the

harvest may last up to February in each year, if the trees bear *Mrig bahar* crop. *Ambe bahar* fruits ripen in the rainy season, when there is little demand for them. When fruits are fully mature, they develop a yellowish colour, and become soft to the touch. Guava fruits are mostly picked by hand, as it is not difficult to bend the branches to pick them when required.

Harvesting

The fruits are delicate and get damaged by rough handling and by dropping from the tree. In the Dholka region, fruits are always picked with a piece of stalk and leaves on them. This helps packing the fruits in the baskets as the leaves form a sort of cushion and packing stuff. In Hawaii, the main harvesting season for guavas lasts from June to October, although a few fruits may be available at other seasons.

Bamboo baskets similar in shape to those used for packing oranges are made use of in packing guava fruits. But guava baskets are of a much larger size than orange baskets and hold 300-400 fruits each. Dry banana leaves are used for packing and for covering the top of the fruit layers. The basket is then labelled and despatched to the market. At Dholka, fruits are all laid in layers in large shallow baskets with straw for packing in addition to the stalk and leaves of the fruits. The whole basket is then covered up with an ordinary piece of cloth and carried to the local market for sale. At Dholka the growers pack large fruits in baskets, while the small ones are sent loose in bullock carts.

Guava analysed by Chace et al and quoted by Winton and Winton (34) contains 21·32% total solids, 12·94% insoluble solids, 0·88% protein, 0·77% citric acid, 4·49% invert sugar, 0·45% surcose, 0·69% total ash and 77 ml. of 0·1 N acid per 100 gm. fruit ash alkaline. It is very rich in Vitamin C content.

Food value and composition

Chace (3) found 0·84% of ash in the pulp of guava. The percentage of constituents as found by him are: K_2O 55·00%; CaO 2·48%; MgO 1·64%; P_2O_5 8·29%; SO_3 3·58%; SiO_2 1·13% and Cl 5·33%.

Daniel and Munsell (7) report the quantitative data of vitamin content of guava as below:

Vit A 200	(international units)	Vit C 300	(Skermar units)
Vit B 14	(,, ,,)	Vit G 35	(,, ,,)

Composition and Nutritive Value of Guava

Name of food	Botanical name	Moisture %	Protein %	Fat (Ether extraction) %	Mineral Matter %	Fibre %	Carbohydrate %	Calcium (Ca) %	Phosphorus (P) %	Iron (Fe) mgs %	Calorific Value per 100 gms.	Carotene (International vitamin A Unit per 100 gms.)	Vitamin B (I. U. per 100 gms.)	Vitamin C (mgs per 100 gms.)	Calories per ounce
Guava, country	*Psidium guajava*	76·1	1·5	0·2	0·8	6·9	14·5	0·01	0·04	1·0	66	Trace	—	299	19
Guava, hill	*P. cattleianum*	85·3	0·1	0·2	0·6	4·8	8·1	0·05	0·02	1·2	38	Trace	—	15	11

The work done in India on the Indian fruits revealed the following composition, mineral constituents and vitamin content of the country and hill guava (21). (See page 262.)

Data collected at Riverside are discussed by Webber (32). Flesh, colour, and degree of acidity as judged by taste have no correlation with vitamin C content. There is a slight indication that within any variety the early ripening fruits will contain a lower concentration of vitamin C than its late-ripening fruits. Most of the data collected on the ripening of this fruit indicates that the vitamin C concentration is likely to reach its peak in the period during early ripening, when the fruits are still firm but are starting to go light yellow.

Canning

Guava fruits are generally full of seeds, and therefore, may be found unfit for canning. Recently, however, it is found that with the improvement of guava varieties, the central core or seed-ball could be removed easily. The outer layer of pulp is utilised for canning. Fully mature fruit with a degree of maturity to be determined through experience, is peeled after thoroughly washing and cut into halves and quarters, depending upon the size of the fruits. If the fruit is too full of seeds, it is sometimes cored. The peeled fruit is kept in 1% brine solution to prevent darkening. It is packed in plain cans and filled with 40° Brix hot syrup. The cans are exhausted for 5-7 minutes and sealed at a temperature of 180-185°F. The sealed cans are sterilized in boiling water for 20-25 minutes and then cooled in cold running water.

Guava jam

Guava jam is a delicious product which has lately been put on the market in the Bombay Presidency. In making jam, all the pulp is separated from the seed, and pieces are cut small and cooked with about half the quantity of water. When the pieces are soft, an equal quantity of sugar is added to the cooked pulp, together with a little of lime juice for flavour. The whole mixture is then cooked again, until the temperature rises to 103°C, or until the material gains a fairly thick consistency. The product is then removed from the fire and poured into clean and sterilised containers, which are packed and stored away until required for use. A little melted paraffin may be poured on the top of the jam in the containers before closing.

For preparing jelly, slightly under-ripe but fresh fruit is washed, cut into slices discarding the damaged portions and an equal quantity of water added together with ¾ ounce of lemon juice or a pinch of citric acid for every lb. of the fruit pulp. It is boiled for half an hour. The juice is pressed out with the hand through a thick cloth or jelly-bag, which is then allowed to settle overnight and the clear juice syphoned off. A tablespoonful of clear juice is tested with an equal quantity of 95% alcohol or methylated spirit. Formation of bulky gelatinous almost solid mass indicates rich pectin, a few large pieces of gelatinous precipitate indicate medium pectin and a small amount of flaky precipitate shows poor pectin. Amount of sugar to be added is directly proportional to the amount of pectin, *e.g.*, to every cup of juice rich in pectin is added one cup of sugar, to that of medium pectin half a cup and to that poor in pectin, sugar is added only when the juice gives satisfactory test after concentration by boiling. The juice with the sugar is boiled (removing all the scum) till the temperature is 221°F or it satisfies the *sheeting test*: Dip a spoon in the jelly and then allow it to drip from above. If the drops are syrupy the jelly is not sufficiently concentrated but if the jelly drops in flakes, the jel point has been reached. Hot jelly is poured into sterilized bottles which are capped immediately. Melted paraffin wax is then poured over the surface of the cooled mass to prevent spoilage.

Guava jelly

Fresh, fully ripe fruit, after washing, is cut into small slices and boiled to softness with an equal amount of water. The pulp is meshed through a fine mosquito net cloth. For every pound of the strained pulp, weigh out sugar: 1½ lb., butter: 2 oz., citric acid: 1 gm., salt: half teaspoonful and colour (edible) just enough to impart an attractive appearance to the finished product. The ingredients are thoroughly mixed and cooled till sufficiently thick for spreading and cutting into pieces of desirable size, which is done in a china plate smeared with butter. After cooling, the pieces are wrapped individually in special wrapping paper and then stored in closed jars.

Guava cheese

The guava, being hardy, is not much affected by insect pests and fungoid diseases. Birds are in fact a more serious pest to guava fruits. The chief insect pest is the scale,

Pulvinaria psidii M. which infests both the foliage and fruits. It is more serious during summer. It is a small pale yellow or green insect found in colonies. At maturity, a woolly growth full of eggs develops on their back. The remedy against this pest is to spray the trees with fish oil rosin soap one lb. to 4 gls. of water or crude oil emulsion 12-15 lb. to 100 gls. of water. Two sprayings will be enough to control the pest, if the under surface of the leaf is washed.

Pests and diseases

Scales

Birds like parrots, minas and crows all damage the semi-ripe fruit on the trees. Watching and scaring the birds away during day time is the only remedy against them. Flying foxes, monkeys and bats attack guava plantations for the fruits in large numbers. Watching during night is very essential during ripening season of fruits. Firing crackers at night often minimises their attack.

Birds and mammals

Fruit flies, namely, *Dacus ferrugineus* F., *Dacus zonatus* S. and *Dacus ferrugineus dorsalis* H. infest these fruits very frequently and lay eggs in them. By the time the fruits are picked for marketing, maggots of different sizes are developed inside, although it is difficult to distinguish outwardly a maggot-infested fruit from a healthy one. No remedy is yet seen to be effective against the flies although a bait prepared from lead arsenate and molasses or clensel is found to serve a good lure for them, as stated previously under the Mango. Disturbing the soil under the plants and exposing the pupae also help in reducing the attack considerably.

Fruit fly maggots

The stems are often attacked by borers *Arbela tetraonis* Moore and the caterpillar. The grub bores the branches which are killed. As a control, either the borer is extracted with a thin wire and then the hole closed with mud, or some cotton wool may be dipped in petrol, chloroform, or carbon bisulphide or even in ordinary kerosene oil and inserted into the hole. The vapours of the volatile material suffocate and kill the insect inside the gallery.

Stem borers

Fruits of guava are sometimes seen shrivelling and turning brown. Such fruits were identified as being attacked by anthracnose. This disease has also been noticed in California, Florida, and Mexico, and occurs in some parts of India. The disease is distinguished by

Anthracnose

circular round decayed areas on the fruits. The disease is caused by the fungus *Gloeosporium psidii* Delaer. As the fruit decays further it gets badly wrinkled. Spraying of Bordeaux mixture is effective against this disease.

Guava canker

Guava canker is another serious disease of guava and is caused by *Physalospora Psidii* Str. and Pierce. It has also been reported from Poona. Infection originates in the bark and spreads rapidly along the stem from one branch to another resulting in desiccation, cracking, decortication, death of the affected parts and finally of the whole tree. Numerous perithecia of the causal organism are found scattered over the dead bark. The disease has not been reported from any other parts of the world. No control measures have yet been devised.

Scab

Scab of guava is common not only in Bombay but in other parts of India as well. The fungus which causes scab is known as *Pestalotia psidii* Pat. It mainly attacks the unripe fruit on the surface of which dark pea-sized *scabs* are produced. These disfigure the fruit and lower their market value. The disease has not been investigated and control measures are yet unknown.

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CHAPTER V

POMEGRANATE (*Punica Granatum* L.)

Pomegranate belongs to the Natural Order *Punicaceæ*, *Punica* being perhaps the only known genus of the family.

Introduction

The fruit is locally called by various names, such as "*Dalimbada hannu* (Kannada), *Dalimb* (Marathi), *Dadam* (Gujerati), *Anar* (Hindi)." It is a popular fruit and is much liked on account of its medicinal value and distinctive taste as a table fruit.

Origin and distribution

The original home of this fruit is not yet definitely known, but is believed to be somewhere in the mountain region of the south-west of Asia extending between Kashmir and Arabia. The pomegranate is grown to an extent in California and Florida, in Mexico, South America, Spain and other Mediterranean countries, Egypt and other parts of North Africa, Arabia, Palestine, Persia, Afghanistan, Baluchistan and many parts of India, Burma, China and Japan. It thrives very well in all tropical and sub-tropical countries. In Russia a midget kind of pomegranate bearing flowers profusely is said to be grown in pots for decoration.

The north-western parts of Pakistan are noted for the production of high class pomegranates. The fruit which comes down to the south from Kabul and Baluchistan is considered extremely fine and commands high price. This fruit has been introduced into cultivation comparatively lately into the plains of India. Utkhuli, Michaelpatti, Vellodu and Penukonda in the Madras Presidency are the important pomegranate growing regions in South India, but in the Bombay Presidency this fruit is cultivated in two important zones, namely, near about Dholka in the northern Gujerat and in Poona, Sholapur and Satara districts of the Deccan. There is a sprinkling of pomegranate plantations in other districts of this Presidency, which goes to indicate the possibility of the extension of this easily grown fruit crop. The total area under this crop in the Bombay Presidency is at present 2,000 acres (1937-38).

In the Presidency of Bombay, the pomegranate is con-

sidered as the poor man's crop owing to the inferior type of soil allotted to it and the neglect with which it is treated in orchards. The sites at the foot of hills or at the top of high lying areas, which retain little or no water and where other crops do not thrive, are usually set apart for the pomegranate. The pomegranate tolerates a soil which is limy or slightly alkaline. Of course, it thrives very well in better kinds of soil where it yields a heavier crop. It prefers a light deep loam.

Soil

The pomegranate succeeds well from the sea-level to an altitude of about 4,000 feet. In Cyprus (21), it is cultivated mainly along the sea-coast. For its successful cultivation, the pomegranate requires a semi-arid climate. In humid climates, the quality of the fruit is not very satisfactory, as, for instance, in Blackden Shore, Florida, Hawaii, West Coast of India, etc. Being a hardy plant, which can stand considerable amount of drought and poverty of soil as well as neglect in cultivation, the fruit has stuck on in India even under the apparently unfavourable climatic conditions.

Climate

In the Dholka region of north Gujerat, the scarcity of water limits the extension of pomegranate cultivation although the soil is loamy and the climate is encouraging to this crop. In the Deccan, the annual precipitation ranges from ten to twenty inches, and this occurs during a short period of about three months of the year. This is not normally supplemented with well or canal water in most pomegranate plantations. The pomegranate trees come into flush and bloom with the break of monsoon every year. The crop is harvested before the effect of the last shower is over. During the rest of the year, the trees are literally neglected. During the summer months, it is a common sight to see the trees standing out prominently with barren branches apparently looking as if they are dried up. With good irrigation pomegranate gets greatly benefited.

Irrigation

Because of its hardiness and ease of cultivation, the pomegranate is considered as an important money crop on poor soils of certain districts of the Deccan. It does not tax the cultivator in any way by requiring much money or labour to be spent on raising the crop. The income though small, is fairly steady.

Economic importance

The extension of pomegranate cultivation is, however, not going on rapidly as far as one would wish, because the quality of the fruit grown under ordinary conditions of soil and climate is not very high. The fruit cracks badly as a result of variations in the irrigation and other cultural methods, or possibly due to the environment. The possibilities and the best methods of preserving the fruit juice are not also yet fully worked out. These considerations limit the extensive cultivation of pomegranates. It is to be hoped that extension will be favoured by improved cultural methods, evolving of superior varieties and of suitable methods of manufacture of beverages.

Limiting factors

The pomegranates grown in the Presidency of Bombay may be divided into two varieties one with white flesh and soft seeds, grown at Dholka, and the other with deep pink flesh and hard seeds grown in the Deccan or known as Alandi or Vadki.

Varieties

(1) *Dholka types* :—Fruits of large size; flesh pinkish-white or whitish; seeds medium soft; juice sweet; colour of rind greenish white.

(2) *Alandi or Vadki* (Deccan). Fruits of medium size; flesh blood red or deep pink when the fruit is ripe; seeds very hard; juice sweet but slightly acidic.

An attempt was made in the Deccan to grow the Kabul variety of pomegranates some time ago without success. The plants were stunted in growth and bore fruit very poorly. The attempt has, therefore, been given up.

The following are some of the well-known foreign varieties:—

I. *Varieties from Baghdad and Palestine:*—

(1) *Selimi* from Baghdad: bears very big fruits weighing one kilogram; fruit is juicy and sweet.

(2) *Roman Chokab* (black pomegranate) is cultivated in Bagdad: fruit is dark coloured with large seeds. It has a tender sweet-sour taste.

(3) *Wellissi* from Palestine is considered to be the best as it is soft seeded and very early to bear.

(4) *Ras-el-Baghi* from Palestine, bears large, sweet and early fruits.

(5) *Suffami* from Palestine produces big juicy fruit with delicious sweet-sour taste. The best specimen of

this variety is obtained from Kabul, Afghanistan and Persia.

II. *Varieties from Spain:—*

(1) *Dulca Colorado.* Fruit big, sweet and tasty.

(2) *Granad Blanc.* Fruit seedless.

III. *Commercial varieties of California.*

(1) *Choodesuy.* Fruit of very high quality; stands transportation well.

(2) *Boomageny.* Fruits large, very juicy, and stands shipment well.

IV. Pomegranates in Cyprus are grouped into three distinct classes, *viz.* (21):—

(1) The sweet pomegranates locally known as *Glykia.*

(2) The sour pomegranates, neither sweet nor sour, but of a mild sourish taste, locally known as *Maifoshika,* and

(3) The sour pomegranate.

V. Indian pomegranates (excluding those of the north-west) are not reputed for quality. Most of the commercially cultivated varieties broadly fall under two groups—the white fleshed and the pink fleshed. The quality and size of fruits, however, vary greatly according to locality. The correct nomenclature and classification of the various indigenous types have not yet been attempted in this country.

An improved strain of pomegranates has been evolved at the Ganeshkhind Fruit Experiment Station, Kirkee, as a result of an attempt to select from the local Vadki or Alandi variety suited to the Deccan conditions of soil and climate. This is named Ganeshkhind No. 1. The fruits of this strain have very soft seeds with pinkish flesh and juice with an extremely agreeable flavour. This strain is under trial and has been vegetatively propagated by cutting. Certain other strains selected for their quality are also under observation.

The following foreign fruits are sold in Indian markets:—

1. *Muskati.* Fruit of medium size; rind russet green; seeds soft; flesh pinkish and sweet;
2. *Kandhari.* Fruit larger in size than *Muskati*; flesh deep red; seeds medium soft; colour of the rind deep red.

3. *Sour pomegrantes*, which generally grow wild in the forests of the Himalayan mountains are as a rule not sold in the fresh condition, but are available as a dried product for use as a condiment in place of tamarind.

The common method of propagating pomegranate plants in the Bombay Presidency is by raising seedlings. Seeds are taken from ripe fruits indiscriminately and sown in seedbeds. When they are of sufficient height, they are directly planted in their permanent place in the plantations. The inferior quality of fruits produced and the general degeneration of the local types from time to time are largely attributable to this method of multiplying our planting stock. In the Punjab and the North Western Frontier Province, pomegranate plants are propagated by hard-wood cuttings. In countries like Palestine and Afghanistan also, pomegranate plants are propagated by using hardwood cuttings on a commercial scale. The cuttings so used are generally ten to twelve inches long and about a quarter to half-an-inch in diameter. Cuttings of fairly mature wood are taken from suckers which spring up from the base of the main stems, and planted eight to ten inches apart in the row. Pomegranate can be propagated by *layering* also. But this method is rather more expensive. In Cyprus (21), pomegranates are propagated either by cuttings or by suckers. These are planted either in their permanent sites direct, or kept for one year in the nursery. In Java, the pomegranates are propagated by root suckers or marcottes (8).

Propagation

In the shallow and stony soils of the Deccan, pomegranate plants are planted, twelve to fifteen feet apart. In lighter but deeper soils, the distance is increased to eighteen feet. At Vadki and Alandi, the spacing varies from twelve to fifteen feet. Usually pits of two feet by two feet by two feet are taken at the required distance and filled with about forty pounds farm yard manure mixed with fine soil. No manure is, however, used in filling pits in some places. Seedlings, which are twelve to fifteen inches in height, are then planted and watered immediately. Planting is usually done in the monsoon in the Deccan, while in Sind and Northern India, pomegranate planting is done mainly in early spring. Some gaps may occur by the death of newly planted seedlings. These gaps have

Planting

to be filled up by fresh planting. When they are once established, the seedlings become hardy, and can stand a considerable amount of drought and such adverse conditions. As a commercial crop, pomegranate in Cyprus is planted at eight to ten feet each way. It is sometimes planted as a secondary or filler crop in young orange plantations too.

Although pomegranate plants can withstand a good amount of drought, they respond very well to adequate water supply.

Irrigation.

In order to get a good growth of trees and a bumper crop of fruits, proper irrigation is essential to the trees. In the Bombay Presidency the usual method of watering is by the bed or basin system. Small round basins are made at the base of each tree, and filled with irrigation water at each turn. As the spacing between the trees is limited, the whole orchard practically gets wet by irrigation and the system amounts to flooding. In order to economise irrigation water, trees are treated for the crop during the monsoon months and almost neglected during the rest of the year. Monsoon showers are supplemented by artificial irrigation only during the months of May and June. If rains fail, irrigation has to be given even during the monsoon months, when fruits are on the trees. Copious and regular irrigation is essential during fruiting season, as irregular moisture conditions in the soil at that period result in a large number of fruits cracking. Where the soil is light, the furrow method of irrigation may perhaps be found useful.

Well-rotten old farm yard manure mixed with household ashes is usually applied to pomegranate plants at the rate of forty

Manuring

pounds per seedling while planting. After this, three to six baskets of old cattle manure alone are given to each tree every year at the break of the monsoon or a little before the trees are treated for the crop. At Vadki, where no manure is given while planting, a couple of handfuls of cattle manure is given per plant about six months after planting. The annual dose of manure then follows at the usual rate mentioned above.

Where moisture in the soil is enough, the pomegranate plants produce a large number of suckers from the base of the

Suckering

main trunk, and form a bush. The suckers hinder the proper setting and development of fruits. They also utilise a large quantity of soil nutrients, that

should properly go to feed the main stem. They, therefore, grow at the cost of the main tree. The pomegranate plants should be encouraged to develop a clean main stem free from suckers. A single clean main stem has several advantages. The tree makes a well balanced erect growth. Fruiting is facilitated. Cultural operations at the base of trees become easier. Lastly, borers and other insect pests do not find suitable harbouring ground for attacking the stem later. Suckers should be pruned off as soon as they appear. They will be few and far between when once the tree has formed a single clean main stem.

Pruning

Pomegranate trees do not usually require pruning except for removing the suckers and giving a shape to the trees. Fruits are borne on short terminal spurs, which have to be at least of two years of age. Popenoe (18) remarks that the wood of pomegranate plants bears for several years, but as the years pass on, the stem loses its fruit bearing habit. New shoots take up this function, and thus the bearing of the tree continues. Little or no fruit is borne in the interior of the plants. It has been observed that heavy pruning of the branches reduces bearing of fruits for the following two or three years at least. As a rule, no systematic pruning is practised on pomegranate trees in Bombay Presidency or elsewhere in India.

Parsons (17) recommends for Ceylon a pomegranate tree with a round shaped head, and this is obtained by short-elongated shoots and thinning out congested growth. Hodgson (11) has outlined a system of pruning in California in order to have a suitable tree form. The method of pruning is simple. The tree on planting, is cut back at twenty-four to thirty inches from the ground. As the buds are produced they are thinned to three to five scaffold branches. These too are cut down to make them stocky. In the next pruning season, the scaffold branches are shortened to three-fifths of their length. New buds arising on these branches should not exceed three in number. The tree should be free from sucker growth. The desired tree form is accomplished by the end of the second or third year.

According to seasonal changes in the atmosphere, there are three flowering seasons a year in the Deccan for pomegranate also (12). The *Mrig bahar* synchronises with the break of monsoon in the Deccan, and it is usually taken advantage of. It is always desirable to attempt only one of the three seasons

annually in order to get a regular crop of well developed good fruits. Pomegranate plants come to regular bearing in their fourth or fifth year. Fruits ripen in six to seven months from flowering. After the rains, that is, in October-November, the trees shed their leaves and at that time the land is ploughed or dug up. The roots of trees are exposed by digging out the soil from the basin to a depth of about six inches, for ten to fifteen days. Fibrous roots which are kept exposed are all pruned neatly and all injury caused to the thicker roots in the course of the operation is treated with coal tar to prevent infection from soil organisms and to expedite healing. The usual dose of manure is then spread on the soil taken out of the base of the trees, and this is replaced after mixing it with manure. The water channels and beds are made, and irrigation follows. These operations continue till about the middle of February, when the first irrigation is given, though sparingly. Watering is gradually increased to normal quantity in the third turn after which this supply is maintained at regular intervals. Flowers appear in about a month from first watering. When the fruits have set, the soil at the foot of the trees is stirred at least once a month. These are the treatments of *Ambe bahar*. In the case of *Mrig bahar*, the trees are treated in April, exactly in the same way as for *Ambe bahar*. The first watering is given about the beginning of May (*Aksha Tritiya*) and the fruits are harvested about six months after. It is generally not possible to treat trees for *Hatti bahar* or the September flowering, because the trees cannot get any rest from active growth during the rainy months which precede. However, when there is a long break in the rains during August-September, and when neither of the other flowering seasons is successfully treated for, the *Hatti bahar* also may be attempted.

Treating the trees for crops

Although due to the mild nature of the Deccan climate, the pomegranate trees may be induced to bear fruit at any one of the seasons described above, the usual cropping season is the *Mrig bahar*, and the fruits ripen in the months of October, November and December. Some growers prefer to have the fruits ripen in the summer months to get market advantage by taking *Ambe bahar*. Pomegranate fruits can, therefore, be had in

Season of harvesting and yield

the Bombay Presidency almost throughout the year. But the right quality of fruit is available only during the winter months, which form the natural cropping season. On an average, pomegranate trees of about ten years of age may bear 100—200 fruits each per annum. Fruits grown in the Bombay Presidency are, of course, inferior in quality to those of Afghanistan and Persia. In Cyprus, the average production is estimated at 2500 to 3000 okes (1 oke=2·75 lb.) per statute donum (14).

Improvement of pomegranate by selection

As mentioned elsewhere, effort has been made to improve the quality of the Deccan pomegranates. The local type has very hard seeds and little pulp, with slightly acid juice. Its continued propagation by seed through several generations has contributed to its degeneration very considerably. Improvement was, therefore, taken up by individual tree selection at the Modibag, Poona, and the Ganeshkhind Fruit Experiment Station, Kirkee, where individual performance record was maintained in the case of a large number of seedling trees for many years, and selection was made of those which had soft seeds, better pulp and sweet juice. Trees so selected have been further propagated vegetatively, and the progeny raised by cuttings is found to possess all the good points of the selected parent. Ganeshkhind No. 1, is found to be an exceptionally superior strain. This is being further propagated for distribution. It is suggested that for substantial improvement of this crop, selection of superior trees should be made in all localities which grow pomegranate and the trees marked out for their high quality of fruits should be further propagated vegetatively. New plantations should be raised only with plants taken vegetatively from such selected trees. Seedling plantations should become things of the past. Or else, the quality of Deccan pomegranates will remain low, and it might further deteriorate.

Fruit cracking

Pomegranate fruits are notorious for their cracking habit. It is a serious trouble in the Deccan. Damage due to cracking is enormous, reaching even up to 50 per cent. of the total crop. It is difficult to attribute cracking of the fruits to any definite causes, as no regular experiments have been carried out on this problem as yet. It is supposed to be due to unequal moisture contents at the roots. It is not known if cracking of fruits is associated with

any causal organism. But, it is no wonder if spoilage due to organisms follows cracking and exposure of the inner pulp. It is suggested that regular irrigation and interculture throughout the bearing age may remedy cracking. The Cyprus pomegranate growers are of the opinion that irregularity in watering and lack of moisture at the roots are responsible for bursting of fruits, which consequently become unmarketable (21).

Pomegranates are a rare type of fruit which keep well for a long time after harvesting. The fruits are harvested when the rind attains the proper colour—yellowish brown in the Deccan type. But often this is not a sure guide to pick fruits. Experienced growers pick fruits when they give a distinct sound of grains cracking inside when slightly pressed from outside. This is tried in a few cases, and all fruits which are approximately of that maturity are picked. Owing to the cracking of fruits, promegranates are often harvested when they are still immature. This tells on the quality of the marketed fruit under the Deccan conditions. Fruits are picked at intervals of a week each, commencing from about the first week of October. As the fruits are firmly attached by strong stalks to the main wood of the tree, it is better to clip them rather than to pull them, while harvesting. Some writers recommend the harvesting of the fruits before they are fully ripe, as this would, in their opinion, minimise cracking.

Harvesting

In a cool and dry place, the fruits keep well for several months. Though the rind loses its striking lustre and shrinks, the quality and flavour of fruits improve by long keeping. It is reported by Hodgson (11) that the fruits improve in quality and ripeness, when stored in cold storage, where they keep well in excellent condition for about six months. The rind shrinks and becomes thinner and tougher. The amount of rag decreases and the seed coat grows more tender and edible.

"In Spain (13) fruits are packed in wooden boxes similar to those used in packing sweet limes. The standard packing quality depends upon the price offered per case of fruits in foreign countries. In California fruits after harvest are sent to the packing house, where they are wiped clean of all dirt. They are then sized, the sizes running from 24 to 110 per box. After sizing, the fruits are wrapped in tissue

Packing

paper. The commercial package is the orange half-box made of six pieces, two each for the top and bottom, and one for each side. With fruits, the package, when ready, weighs about 35 to 40 lb." In the Deccan, pomegranates are packed in bamboo baskets without proper sizing or grading. The baskets contain fifty to seventy-five fruits each.

The pomegranate baskets are carted in bullock carts to the Poona and other city markets. The carts are loaded with two layers of such baskets.

A good deal of business is carried on in pomegranate rind as a dyeing material both locally in Cyprus and for export. It is estimated that over 30,000 okes (14) are in use in the local cloth dyeing industry. The export in rind is mainly confined to Egypt and Greece, which in 1929, amounted to 57,435 okes valued at £479. All the parts of the pomegranate plants are used in one form or other. Pomegranate juice contains citric acid. Its sugar content is more than that in apricots and peaches. In the Balkan peninsula, a kind of wine is prepared from pomegranate juice and this wine is considered superior to grape wine. Pomegranate juice is used sometimes against leprosy.

Uses of pomegranate

"The pomegranate fruit is known for its medicinal properties. The bark and rind are recognised astringents employed in therapeutics in dysentry and diarrhoea. The rind when boiled has for many generations past been the remedy for tenia. A jet black smooth writing ink is also made out of it. A cooling drink known as "grenadine" is also made of the pulp by adding water and sugar for use in fevers. The bark of the stem and root is used for slimming purposes.

"The fruit is very refreshing and hence is eaten fresh in hot countries. The sweet type is said to be a mild laxative. The intermediate type between sweet and sour is reputed to be good on the inflammation of the stomach and for heart pain. The pomegranate fruit is highly commended for its delicacy as possessing flavours like the apple. The plant is highly valued for its decorative effect in the United States of America. With effort it can be trained into trellis to divide portions of the same garden with considerable effect. The tree is also grown as a hedge or wind break on sandy slopes."

Fresh juice of pomegranates retains its flavour and keeps

well when bottled after sweetening with sugar. The grains of pomegranate are first collected after removing the skin and other portions of the fruit. They are then crushed in the meat-mincer and the juice squeezed through a thick cloth or in a basket type wooden press. The pomace is mixed with one fourth its quantity of water and heated a little (160—165°F) to extract the colour. The extract is again squeezed through a thick cloth and the two extracts are mixed. Half this quantity of sugar is added and the sweetened juice is preserved (after regulating the acidity to 1·5—2% with citric acid) with 0·1 per cent. sodium benzoate in air tight sterilized bottles which are then stored in a cool dry place. Siddappa (19) also produced bottled sweetened juice by heating it to 175 to 184°F, cooling it quickly and after allowing it to stand overnight, decanting or filtering it. The filled bottles have to be pasteurized at 175—180°F. for 30 minutes. In one good variety the juice was 40·1% of the entire fruit and total solids varied from 17·3 to 18·5% of the juice, acids running from 0·81 to 1·23% as citric acid.

Pomegranate juice

The pomegranate fruit is attacked by *Virochola isocrates* Fb. a small caterpillar locally known as *sursa*. The butterfly lays white eggs on flowers or small fruits. The eggs hatch out into caterpillars which bore into fruits and buds, and feed specially on seeds, till these are full-grown. The attacked fruit appears sound outwardly but is severely damaged inside. The full-grown caterpillar comes out of the fruit and ties its stalk to the main branch with its fine web to ensure against its falling and pupates inside the fruit. By way of control, infested fruits should be removed and burnt or buried. Covering the unaffected fruit buds and small fruits with small paper or cloth bags is very effective. It was found that 92% of the fruits bagged in this manner yielded very good fruits on full maturity, whereas only 47% of unbagged fruits escaped the attack of the caterpillar. Paper bags can last for two or three seasons, if used carefully, thus economising the cost of bagging. Bagging is, however, economical only when fruits are of a high quality.

Fruit borer

Chikta is caused by small white insects *Aleurodes* sp. found in large numbers on the lower surface of leaves. They secrete copious amount of honey-dew on which black mould may

develop. The damage is done by removing the sap by sucking as well as interfering in the photosynthesis which results in malformation of fruits. The pest is controlled by spraying with rosin compound prepared with the following formula:—

Chikta

Rosin	5 lb.	Powder rosin and mix it with soda in a vessel and add enough water. Boil the mixture and keep on adding a little of water till the material is clear and coffee coloured.
Washing Soda	1 lb.	
Water	5 gals.	

When ripe, it should not give a milky appearance, when a drop of water is added to it. This stock solution should be further diluted for spraying in the ratio of 1 : 6.

Stem borer

In old and neglected gardens particularly, the main trunks of trees will be found badly infested with stem borer caterpillars (*Arbella* sp.). Wherever the caterpillar is eating inside, a small hole will be seen and the network of the dried excreta of the insect will be found outside the hole. This has to be cleared and the insect should be extracted by inserting a fine hooked wire into the hole. If this is not possible, a small cotton plug dipped in petrol, chloroform, or kerosene oil may be inserted and the hole closed with mud. The insect inside will die of suffocation caused by the vapour of the chemical. Considerable damage to plantations is caused by this stem borer. All the bark and other portion eaten by it should be cleaned and the damaged parts treated by coal tar to enable the wound to heal up.

Fruit rot

Fruit rot is at present the only known trouble caused by fungus in the case of pomegranates in the Bombay Presidency. The fruits rot badly, partially or wholly and become useless. The only remedy is to remove all affected fruits and burn them. The fruits may be sprayed with Bordeaux mixture (5: 5: 50) as a preventive remedy.

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CHAPTER VI

PAPAYA (*Carica papaya* L.)

Papaya is an exotic plant in Western India, having been introduced into this tract comparatively recently. It has since gained considerable commercial importance. It is second to banana in regard to yield of fruits and money income in the districts of Poona and Nasik, and other tracts surrounding large city markets. It is also grown widely in Gujerat. Its cultivation is easy, it gives quick returns and adapts itself to diverse soil and climatic conditions. Papaya is also gaining popular favour as a table fruit all over this country. The importance of evolving and growing superior types of papaya cannot be over-estimated, especially in view of its commercial significance and the possible future developments. But as in the case of all other fruits in India, papaya has not so far attracted the attention of plant breeders in this country.

Introduction

Tropical America is believed to be the home of papaya. The plant is now widely distributed, being grown on a large scale in India, Ceylon and Malaya Archipelago, in Hawaii, and in Australia as far as Sydney. In the United States of America the cultivation of papaya is restricted to Florida and California. Its distribution in the Bombay Presidency is mainly restricted to the Deccan and Gujerat Divisions. The districts of Ahmedabad, Broach and East Khandesh grow papaya to some extent. In the year 1925-26, the total area under papaya in the Presidency was a little over 500 acres, while it stood at 1,856 in 1933-34 and at 927 acres in 1937-38. The area in Bihar is 9,700 acres, in U. P. 1672 acres and in Assam 10,000 acres. In the Baroda State and Kathiawar, the cultivation of papaya is extending recently by leaps and bounds, the Honey-dew "variety" gaining much popularity in new plantations. In South India also this fruit thrives, but it is not very popular owing to

Origin and distribution

some prejudice against it in the public mind, particularly in Tamilnad.

Papaya belongs to the family *Caricaceae*. This fruit is known by different names in different countries of the world. Papaya, apaya, papaja, papaw, and tree melon are some of the more common terms used, although the term papaya is the most widely adopted one. The name "Papaw" which applies to *Asimina triloba*, Dunal, a tree native to the United States of America is also sometimes wrongly used to designate papaya. To avoid confusion it seems most necessary that the word papaya be used as the only correct name for the *Carica papaya*. Apart from the cultivated types, there are several species of the genus *Carica*, which are grown extensively in different parts of the tropics, such as, *Carica Candamarcensis*, *C. erythrocarpa*, *C. quercifoli*. *C. papaya*, however, is the only useful species under cultivation. Being chiefly a diœcious plant, cross-breeding is the rule in papaya. It is further propagated mainly by seeds. This practice gives rise to innumerable variations in tree and fruit characters. It has, therefore, been extremely difficult to classify the known types of papaya, and to keep them pure for any length of time. Similarly, it has been difficult to fix up any standard nomenclature of known varieties in its case. The names of so-called varieties or types are derived largely from the places where they were originally recognised, and there exists a good deal of confusion as to the distinctive characters of these varieties.

Varieties

Carica papaya includes a large number of horticultural types such as the Australia, the Blue Java, the Madgascar, the New Zealand, the Gujerat, the Ranchi, the Washington, the Honey-dew, the Bangalore, the Singapore, etc. But the Gujerat, the Washington and the Honey-dew are the only types which are favoured in Western India. The following is a brief description of these:—

1. The Washington papaya:—Tree is fairly dwarf; stem has purple rings at the nodes; petiole dark purple; growing darker towards the lamina; flowers deep yellow; fruits borne in large numbers, large and ovate; pulp sweet and flavour agreeable; seeds few; fruit keeps better than the other types grown in the Presidency. The flesh is free from the dis-

SINGAPORE PAPAYA TREE WITH FRUITS.

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agreeable smell and slightly bitter taste which are characteristic of the local Gujerat type and, therefore, makes this fruit very popular.

2. The Honey-dew:—Tree of medium height; bears fruits low on the trunk and heavily; flowers resemble those of the Gujerat type; fruit elongated and the pulp is extra fine, sweet and has very agreeable flavour; seeds not many. This type is lately extending in cultivation in Gujerat and Kathiawar areas. It is locally named *Madhu-Bindu*.

3. The Gujerat:—This type has trees of medium height and bears very heavily. It differs from the Washington in having green or yellowish green petiole, leaves and stem; flowers white; fruits are bigger and longer than those of the Washington. Seeds are many. Fruit is fairly sweet, but has a slightly objectionable flavour and is somewhat bitter.

Due to propagation by seeds there are a large number of variations in each so-called variety, and, therefore, there is a good deal of confusion in the correct identification of the types. All papaya types are diœcious but hermaphrodite trees in the same type are not, however, uncommon.

Soil

Since the papaya tree is evergreen and bears flowers and fruits for the most part of the year almost continuously once it comes to bearing, it prefers a rich and well-drained soil. It may grow on a poor soil with heavy manuring and watering, such as in the laterite soils of this Presidency. Soils with murum at about two or three feet below the surface are congenial to papaya trees. They do not thrive in deep clayey soils as may be observed in the Khandesh, Nasik and Poona districts. Trees grown on poor limy soils give few and small fruits. On loamy soils, the papaya trees make good growth. A thorough drainage is absolutely necessary for the good health of the trees, as otherwise they suffer much from stagnation of water. The unhealthy condition of trees brought about by water-logging or over-irrigation is recognised by the foliage turning yellow and by the dropping of the lower leaves prematurely. It is very necessary that papaya plantations are thoroughly drained in the Konkan area where rainfall is heavy. It is observed in the district of

Poona that whenever there is heavy rain, which might flood the papaya orchards, trees suffer from collar rot caused by a moisture-loving fungus *Pythium aphanidermatum*. Young plants are more susceptible to this disease than older ones. It is essential that the field should be perfectly levelled and well-drained to avoid such diseases. This precaution also holds good for orchards which are irrigated by canal water.

Climate

Papaya grows luxuriantly in all tropical climates. The chief limiting factor for its growth and fruiting appears to be the occurrence of low temperature and frost. If the atmospheric temperature falls to about 35°F, it does considerable damage to the growth of papaya trees. Very often a strong wind coupled with low temperature destroys the whole crop. Lack of sufficient warmth in the atmosphere always retards maturing and ripening of the fruits. A dry warm climate tends to add to the sweetness of the fruits. Excessive moisture affects the quality of fruits adversely. It is due to these reasons that papaya fruits grown in the dry districts of the Deccan are priced more in the Bombay market. The papaya stem is sensitive to strong winds and is, therefore, required to be protected from exposure to them, lest the trees break down. In high lying areas where the trees are exposed to strong winds or storms, suitable windbreaks are essential to protect the trees. Such windbreaks also save the trees to a great extent from damage caused by cold winds or when frosts occur.

Propagation

The most common method of propagation of papaya is from seeds. For this purpose, well-matured, large fruits borne on female plants are collected and preserved in a safe place until they are properly ripe. They are then cut open, and the seeds are carefully extracted on trays. They are washed and dried in the sun or shade and are stored in bottles or in clean tins till they are required for sowing. Fresh seeds may, on washing, be mixed with fine cold wood ash which absorbs the slimy coating on them, and helps to keep the seeds separate on drying. The seeds retain vitality for several years if carefully preserved from insect attack, although it would seem that this fact is not true in all papayas and in all places.

The best time for raising papaya seedlings in the Bombay Presidency is the monsoon, that is, from about the middle of June to

the end of October or November. Sowing afterwards will not give satisfactory germination due to cold. The moist warm weather of the monsoon favours rapid germination of seeds. If seedlings have to be raised on a commercial scale, they are grown in beds on the ground. The site selected for seedbeds is dug or ploughed and then made friable by keeping it fallow for some time. On making it perfectly level, raised beds of convenient size, roughly six feet by three feet, are made six inches above the general ground level. Over them a layer of river soil three inches deep mixed with half the quantity of leaf mould and farmyard manure is spread and the surface is made perfectly level. Papaya seeds are sown half-an-inch deep and an inch apart, in rows six inches apart, and watered gently with a can having a fine "rose". If there be any likelihood of heavy rains or excessive sunlight, the seedbeds should be protected with thatches. The seeds take about three weeks for germination, which may be hastened by moist heat. After about two months more, when the seedlings attain a height of nine inches to one foot, they are transplanted in their permanent places. Planting is done at eight feet distance each way and the number of pits is nearly 700—800 per acre. Two or three seedlings are generally planted in each pit in the Deccan, and therefore an acre of land will accommodate 1400—2400 seedlings. In Gujerat and Kathiawar regions, the spacing in papaya is 10 feet, and there will be only 400—500 pits and about 800 to 1500 seedlings in an acre. Seedlings raised in beds on the ground do not stand transport for more than about two days. It seems, therefore, better to raise them in flat boxes. While taking the seedlings out of beds for planting, much damage is usually caused by injury to the roots. It is obviously safer to transplant seedlings raised in boxes than those raised in the ground. A suitable size of the sowing box is 2 ft. by $1\frac{1}{2}$ ft. by 9 inches. It was found in the Madras Presidency that during the rainy season, when the weather is very humid, papaya seedlings stood transplanting even with their roots naked, provided the tap roots were not severely injured and that the transplanting was done on a cool day, preferably in the afternoons, and also a partial defoliation was done at the time of lifting them from the beds. Transplanting under such weather conditions is specially successful if the seedlings have been raised in pots or boxes. An attempt was made at the Ganeshkhind Fruit Experiment Sta-

tion, Kirkee, to find out the difference made by transplanting papaya seedlings from seedbeds, and sowing seeds direct in the permanent places in the field. It was observed that the former method was much more economical, and contributed to a better stand in the field in the long run. The reason for this is that the seeds do not always germinate properly in the field and the tender seedlings die away in their earlier stages of growth under the exposed field conditions.

Vegetative methods of propagation

The papaya plant can also be propagated from cuttings and grafts. Propagation from seeds is, however, preferred, because the vegetative methods of propagation are not economical. If pure lines of diœcious types of papaya are developed, the need for vegetative propagation will not arise in this fruit. It is reported that grafted plants do not also make vigorous growth. The growers have returned back to seed propagation. In the Philippine Islands, a method of propagation of papaya plants by root cuttings has been evolved. Roots of medium size from a full grown tree are selected, and cuttings of the length of 10-15 cms. are planted in nursery beds made of sand. These cuttings are kept moist and in about four weeks, the adventitious buds develop and the cuttings grow into vigorous plants. A number of workers in India have successfully, raised papaya plants from cuttings. The rooted cuttings are seen to thrive properly, when small branches are taken with a heel from the parent tree. Cuttings made of very old or very immature parts of the plant rot, in the bed and do not sprout readily. Papaya can be grafted with success when the operation is carefully done. According to Higgins and Holt (18), an attempt was made by Rolf to propagate papaya by enarch grafts. Later, cleft grafting was adopted with success and it consisted of inserting scions from shoots to two-month-old seedlings. The rootstock is headed off at a suitable height, and then the cleft is made to receive the scion. This method brought about early bearing. At Sabour (Bihar), a number of papaya plants were raised during 1934-35 by cleft grafting, and these were later reported to have borne crop earlier than seedling trees of the same age. In Java and elsewhere (14), side grafting in the dry season is successfully employed. Tachdjian(33) considers that papaya seedlings should be 20-30 cms. high at the time of grafting, and these when grafted, fruit in eight months.

For raising a papaya plantation, the site is ploughed and harrowed ordinarily in the summer, as many times as possible, until a good tilth is obtained. Then it is levelled and pits of the dimensions 1½ feet by 1½ feet by 1½ feet are taken in most places, eight feet apart each way. The size of the pits may vary according to the nature of the soil, deeper clayey soils requiring larger pits than loamy soils. The surface soil is usually thrown on one side of the pit and the subsoil on the other as in the case of other fruit tree plantings. Pits are left exposed for a few days for weathering. They are then filled with surface soil, mixed with well rotten farmyard manure at the rate of 40-50 lb. per pit. Some also apply old bone meal at the rate of three pounds per pit. The pits are then marked with small sticks, and left over till the planting season. At the advent of the first monsoon, it is a good practice to sow sann hemp (*Crotolaria juncea*) for green manuring the soil during the season prior to planting papaya.

Preparatory tillage

In order to determine the proper spacing required by papaya trees, plants were planted in a trial at Poona at varying distances from two feet to eight feet each way from plant to plant. It was observed that papaya plants thrived best when the distance of eight feet was given to them. It was also noticed that the thickness of the stem was directly proportional to the spacing. Ten feet spacing is adopted in Northern and Southern India by many growers while others adopt even 5-6 feet. This distance facilitates inter-cultivation. The Ceylon practice is to space plants at twelve feet each way. In Florida the planting distances vary from six feet to ten by ten feet with different types.

Spacing

Papaya plantations are raised in the Bombay Presidency in two ways, namely, by sowing a few seeds *in situ* where the trees are required, and by transplanting seedlings from seedbeds. In the first method, a few seeds are sown in the basin direct, where plants are desired to be raised in the field. This practice prevails in Khandesh districts. After the seeds germinate, the extra seedlings are removed, retaining only two or three vigorous ones. In the second method, seedlings are raised in seedbeds and transplanted in the field. Raising of seedlings *in situ*, as explained already is a more expensive method. It is observed that self-sown papaya trees take a

Planting

longer time for flowering and the fruits borne on them are smaller in size than those on transplanted trees.

The papaya tree responds readily to copious watering in well-drained soils. Though a succulent tree, the papaya does not demand as much water as the banana. Regular and judicious irrigation influences the proper development of fruits favourably and induces the tree to bear larger and more fruits. In the Deccan, papaya trees are irrigated once in eight to ten days in winter, once in six days in summer, and occasionally as required during the break of rains during the monsoon months. The quantity of water given depends upon the nature of the soil, but filling basins well is the usual practice. In the alluvial soils of Gujerat more frequent watering is needed for papaya trees than in the heavier soils of the Deccan. In the course of experiments carried out at the Ganeshkhind Fruit Experiment Station, Kirkee, it was noticed that the ring system of irrigation is more advantageous than square beds, as the former holds comparatively less water. The square beds perhaps hold more water than the trees really need. It seems advisable to adopt either the ring or the sloping basin system of irrigation in the case of papaya as this system prevents irrigation water from coming into direct contact with the stem, thus preventing the incidence of collar rot. In adjusting the water requirements of papaya trees, care has to be exercised to see that no water-logging occurs at the roots. In Ceylon, and in the West Coast of South India artificial irrigation is found usually unnecessary for papaya trees, owing to the good distribution of rains over a large part of the year. This fact makes papaya cultivation in those parts very cheap.

Irrigation

The papaya tree is considered a heavy feeder and requires plentiful manuring in one form or other, as the tree bears heavily and throughout the year. Farmyard manure, sheep dung, wood ash, bone meal or bone ash, and oil cake are all used for papaya with success in different districts of the Bombay Presidency. In the Deccan about forty pounds of farmyard manure is usually applied to each pit while planting seedlings. A second dose of manure at the rate of 80 to 100 lb. of farmyard manure is given to each bed about four or five months after transplanting, just about the time of flower-

Manuring

BEAN CREEPER TRAINED ON PAPAYA TREE AS AN INTER-CROP.

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ing. The third dose of about the same quantity as the second is applied when the trees are about a year old, preferably at the commencement of rains. Round about cities like Bombay and Poona, where papaya fruits find a good and ready market, bone meal or bone ash is also applied in September after the heavy monsoon showers subside. In the district of Nasik (10) cowdung or wood ash or both are chiefly used for this crop once a year. Near Ahmedabad, Pattan and Poona excellent papaya fruits, big in size and sweet in taste are produced on effluent water. In Sind sheep dung or wood ash or both are used for the trees twice a year. Amongst the best fertilisers for papaya are also found to be decaying vegetable or animal matter and house sweepings. Barnett (4) suggests that a mixture of three parts by weight of superphosphate, one part of sulphate of ammonia and one and a half part of sulphate of potash will promote growth of trees as well as improve the quality of fruits, if the mixture is applied at the rate of two pounds per tree. Sulphate of potash if doubled in quantity may possibly enhance the keeping quality of fruits. Farmyard manure is undoubtedly one of the best manures for the crop. Pope (25) states that the application of farmyard manure to the soil is beneficial in papaya cultivation and adds that good results have followed the addition of complete chemical fertilisers of the following composition:

	lb.
Superphosphate	800
Sulphate of potash ..	315
Nitrate of soda	250
Sulphate of ammonia ..	190
Black volcanic sand ..	445

One pound of this mixture was worked round the stem of young papaya plants twice in the first year at intervals of six months each. Later, as the plants grew larger, applications of two pounds each were made.

Inter-crops

When papaya is grown as the main crop, low growing vegetables of short duration such as chillies (*Capsicum* sp.), onions, cabbage, knolkohl and tomatoes may be grown as inter-crops for about six months from planting of papaya seedlings. After the plants grow bigger and shade

the area, it is not possible to grow any inter-crop of the type mentioned above profitably. But it is now experienced that papaya trees when they are a year or more of age, and when they have grown fairly tall with bare stems below the fruiting region, can be well utilised as supports for creepers of beans. The beans are planted round the stem of trees in the ground at the rate of four or five seeds in each bed. When they germinate and begin to grow, the creepers are trained to climb the papaya stem up to the fruiting region and not higher. All attempts of the creepers to disturb the fruiting region of the trees is checked by keeping the growing tops clipped at the proper height. The creepers do not suffer from the shade of the papaya trees, and yield an additional income without much extra cost or trouble. These beans should not be grown in the earlier stages of the papaya plantation as they are fast growers and might unduly disturb the main crop. Small and large plantations of papaya alike may yield a good income per tree from the beans alone, which are used as vegetables.

The papaya tree itself is often grown as an inter-crop in plantations of other fruit trees, where the spacing required for the main crop is more than fifteen feet. One or two rows of papaya planted in the interspace of the main crop yield a very considerable profit during the short period of three or four years, when papaya trees complete their economic life cycle, without disturbing the main crop like citrus, mango, sapota, and guava, which take a much longer time to come to bearing and would require to have the whole area left to themselves, after that.

If papaya plants are planted about ten feet apart each way, the cultural operations in the plantations can be carried out by bullock power. Two ploughings and two harrowings cross-wise are necessary in such plantations every year. Only the space left unploughed near the trees may be hand dug. After manuring, beds and water channels are prepared. Besides, occasional stirring and weeding of the beds of the trees have to be done. Where papaya is raised under irrigation, beds and channels may all be removed before the monsoon breaks, by ploughing the area, and the whole ground left practically levelled. If it be a very heavy rainfall tract, then suitable trenches should be opened

Interculture

out in between the rows of trees, in order to drain out excess of rain water. In lighter soils it is necessary to raise a small mound of earth at the base of the trunk of papaya trees in order to support them from falling due to strong wind, or when the soil is soft due to irrigation. Since papaya is a shallow rooted plant, no weeds should be allowed to grow underneath it. It is not very desirable to plough the area very deep for the same reason. Frequent light cultivation and stirring the soil in the beds serve to increase the quality and quantity of the fruit crop.

Pruning of papaya

In Ceylon, planters prune the top of papaya seedlings, when they are about five months old in the plantation. This practice encourages side shoots which are said to produce a higher yield. A large majority of male trees found in the plantation are also cut down about the same time. There is also a conception that if such male trees are headed off and left to produce branches, they change their sex and produce fruits later on. This conception does not appear to be well-founded and was actually proved wrong in a trial with a large number of trees at Kodur (Madras). Change of sex in papaya trees might occur occasionally in some trees, but such changes are not certain.

Development of fruits

In about five months from transplanting the seedlings, flowers begin to appear and fruits set. The fruits take another six months to ripen. Thus, ripe fruits may be harvested in about a year from the time the seedlings are set out in the plantations. From this time, flowers appear continuously and fruits set and mature without a break for about nine to twelve months. Although papaya trees may bear flowers and fruits longer than this, fruits which develop later on become small and the bearing is not considered economic after the trees are about two and a half years old. In the Deccan, it invariably happens that there is little ripe fruit of papaya available in the market from July till about the end of October. This shows that in winter on account of cold, the trees do not produce flowers and if at all they do, the flowers do not set fruits. This state of affairs happens from December to the beginning of March. Naturally, therefore, a gap in the harvest is caused during the months of August and September. It is reported that in Hawaii (18), the

quality and flavour of papayas depend partially on the season and the amount of rainfall.

In the diœcious pistillate or the pure femal eplant of papayas, flowers are commonly borne on short peduncles in the axil of each leaf. The number of flowers on each peduncle varies from three to four. Normally the terminal flower which is the oldest, develops into a fruit. As this fruit develops vigorously, the other branch flowers are automatically superseded. As a general rule, only one fruit develops into normal size in the axil of a leaf. Sometimes, other flowers also develop into fruits and crowding takes place, which becomes intense as the plant grows older. In old trees, the internodal space decreases and consequently there sets in a competition between the developing fruits, which cannot grow into large normal size. In order to allow only a limited number of fruits to develop properly, so that they attain a good size, thinning becomes an essential operation at this stage. Thinning is easily and quickly performed with a knife, when the fruits are still young. Experiments on thinning of papaya fruits were carried out at the Ganeshkhind Fruit Experiment Station, Kirkee, in the year 1910 (20). It was observed in these trials that, though the individual fruits increased in weight in the case of plants where thinning was practised, the total yield obtained from them was not enough to warrant the reduction of the number. The difficulty is to hit on exactly the proper number of fruits to be thinned out, to get the highest weight compatible with the smallest number of fruits retained. This result can only be obtained by practice. It may, therefore, be recommended that only such fruits may be removed as are expected to go bad, or to be flattened and remain undeveloped by being pressed in between normally developed ones. Experimental data on this question are not sufficient.

Thinning of fruits

Observations recorded by some writers (9) show that a well-formed papaya fruit containing no seed is not of uncommon occurrence. During the months of August, 1923, to February, 1924, there appeared in the Ganeshkhind Gardens orchard, seedless fruits on eleven female trees in the following numbers :—

Seedlessness in papaya

Month.	Total number of fruits harvested.	Number of fruits found seedless.
1923.		
August	14	Nil
September	40	Nil
October	26	4
November	21	8
December	9	7
1924.		
January	18	9
February	14	11
Total ..	142	39

This raised the question whether this lack of seeds was due to lack of pollination or lack of fertilisation. To solve this, flowers on pure female trees were enclosed with paper envelopes or cloth bags. In every case a bagged flower yielded a fruit containing no seed, but smaller in size than fruits developing seeds in the usual way.

In the Punjab, on the Montgomery Fruit Farm, female papaya trees yielded seedless but otherwise normal fruits when left open to natural conditions. No male papaya tree was, however, found within a radius of several miles and evidently pollination could not have taken place.

Partial pollination results in partial setting of seeds, the carpels corresponding to pollinated branches of the stigma alone setting seeds. On one and the same tree, fruits having seeds all over the pulp area and fruits with seeds at the stigmatic end only, as well as those that are absolutely seedless are often found.

In the course of investigations on papaya at the Hawaiian Agricultural Experiment Station, a papaya tree was found bearing seedless fruits (17). In order to throw some light on the causes responsible for this occurrence, a few flowers on this tree were hand pollinated, while others were closed in paraffin paper bags to prevent pollination by natural means. Some flowers

that were enclosed and unpollinated failed to produce fruits, the pistils falling off within a week, while some others produced seedless and small-sized fruits. It is, therefore, inferred that pollination is not always necessary for the setting and development of fruits and seedlessness may occur even when flowers are exposed to pollination and have the same opportunities to get fertilised as those on the surrounding trees, which produced normal fruits containing seeds. Possibly in the former case, the pollination is ineffective due to some defect in the stigma or the ovary or some other cause. Some investigators believe that seedless papaya fruits are insipid in taste. Usually such fruits are small and the layer of pulp in them is thinner than in seeded fruits. It is, therefore, not advisable according to them, to encourage the development of seedless fruits on the trees. This may be true under certain climatic conditions, but seedless fruits developed under the Poona, Sabour and Kodur conditions were not insipid. They are on an average undoubtedly smaller in size than seeded fruits, but are equally good in taste.

Limiting factors

The extension of papaya cultivation depends upon, beside the availability of irrigation and not too low temperatures for the evolution of desirable types which will retain their characters in successive generations, and which will have a large proportion of bearing trees, more pulp, better colour and high commercial storage value of the fruits. If these characters can be combined in a type, the cultivation of papaya can be enormously extended in this country. The extension of papaya cultivation is further hindered by a lack of proper marketing, transport and storage facilities suited to this highly perishable fruit. The preservation of surplus fruits in seasons of heavy harvest and manufacture of papaya products are also essential in order to encourage further cultivation. There is also an unfounded but extensively held belief in parts of South India that papaya fruit is not a desirable food and causes particularly some serious ailments in women. A ripe papaya fruit eaten in moderation is one of the most healthful of foods to all classes of people of both sexes and it is a pity that the erroneous impression now prevalent among certain people should hinder the extension of area under this valuable fruit.

In the case of papaya, the problem of sex is very

complicated. Knowledge and study of papaya flowers, therefore, become essential. The following classification of papaya plants according to their flowers (15) is recognised:—

Sex in papayas

1. *Diœcious pistillate*, with large sessile pistillate flowers in the leaf axil. This is the normal female plant.
2. *Diœcious staminate*, with long narrow tubular flowers arranged on long peduncles, hanging from axils of leaves. This is the normal male plant.
3. *Andromonœcious* with male and hermaphrodite flowers on long peduncles.
4. *Polygamous*. A. With male, female and hermaphrodite flowers on the same tree on long pendunces.

   B. With male, female and hermaphrodite flowers on the same tree, the hermaphrodite flowers being of two types, one with ten stamens and the other with five stamens. Fruits are long in shape.
5. *Staminate*. A. With staminate flowers on short peduncles directly in the axils of leaves.

   B. With many hermaphrodite flowers on long peduncles.

   C. With separate staminate and clusters of staminate flowers with hermaphrodite flowers. This type yields long fruits.
6. *Hermaphrodite*. A. Hermaphrodite flowers on long peduncles.

   B. Hermaphrodite flowers with few pistillate flowers.

   C. Hermaphrodite flowers with many pistillate flowers.

It may be remembered that none of these types is fixed and it seems that the papaya is still in a plastic condition so far as its sex is concerned. The papaya plant is known to change in the course of its life history from being staminate to hermaphrodite and then to pure pistillate. The change is gradual. In the beginning the plant may have staminate flowers only. After some time it may bear a few hermaphrodite flowers along with a majority of staminates. Then the hermaphrodites may predominate, until in the succeeding stage a few staminate

only may be seen together with a few pistillate and with a large majority of hermaphrodite flowers. In the next stage pistillate flowers may predominate until the hermaphrodites totally disappear. In South Africa (19) the distribution of male trees is reported to be about equal to the others in the papaya plantation. In an orchard at Poona consisting of 215 papaya trees, 33 per cent of the trees were observed to be pure females, 5 per cent pure males, and 62 per cent hermaphrodites. A much greater percentage of males has been observed in papaya plantations in Bihar and Madras, so that the elimination of male trees has come to be recognised as a very important problem.

Changing the sex

In some parts of India, as also elsewhere, it is believed that there exists some relation between different systems of roots in young seedlings in seed beds and their sex. A suggestion has also been advanced that it is possible to detect the sex in papayas by the use of a metal indicator, while some others have said that sex could be determined from the location of seeds inside the fruits, and also from the size of seeds. Elaborate trials conducted at Kodur (Madras) have shown that all these assumptions are unfounded. Sakurai (30) has also obtained negative results in regard to the relation of the sex to the location of seeds in different parts of the papaya fruits, as also of the size of seeds to sex. He further states that no relation exists between size of seedlings in seed beds and their future sex. Change of sex of a male by pruning or topping of the tree, cannot also be depended upon to give uniformly successful results. Reyes (28) has shown that contrary to the existing belief, the margin of the intial leaves, the colour and vigour of the stem, and the size or extent of the root systems of young papaya seedlings are not individually or collectively associated with male or female characters. He also did not find any positive results in regard to the control of sex by cutting off the central root systems or topping once or even twice or thrice. The light topping consisting of pinching off of the terminal bud was followed by slight sex changes, but several forms produced no positive response. Hofmeyr (19) found that no ground exists for the assumption that the male trees are more vigorous and, therefore, the elimination of vigorous seedlings while transplanting is merely the destruction of best plants.

As it is difficult to determine the sex of seedlings at the time

of planting, generally two or three seedlings are planted together in each pit in the Bombay Presidency, and when flowers appear on them, male and hermaphrodite plants are removed, leaving the females with a very few male plants in the plantations.

Improvement in papaya

As papaya presents varied sex problems, there appear to be possibilities to breed papaya with a view to combine most desirable characters and subsequently propagate such a newly evolved type vegetatively or by self-pollination or by sib-mating in order to keep it stable through generations. According to some authors the ideals which the breeder should have in mind in breeding the most desirable type of papaya are outlined below:—

1. Vigour of tree.
2. Early and low-down-on-the-trunk fruiting habit.
3. Freedom from branching habit.
4. High productivity.
5. Hermaphroditism.
6. Suitable size of fruits.
7. High yield of papain.
8. Uniformity of shape.
9. Uniformity in ripening.
10. Appearance of colour before softening.
11. Attractive colour of flesh.
12. Easily separable placenta.
13. Agreeable flavour and taste of pulp.
14. High keeping quality.
15. Ability to produce progeny with the least number of variables.

Hofmeyr (19) considers that contrary to the existing belief, a given papaya strain can definitely be improved by selection in spite of the trees being diœcious, particularly if selections are made from the centre of the plantations, when there are neighbouring groves. The other way out of this difficulty would be to select and purify by isolation and artificial pollination selected strains of known quality. Seeds thus produced should be certified as belonging to such strains and distributed for raising plantations in the country. No seeds produced in the open plantations under natural conditions should ever be used for raising new plantations, if mixture

and deterioration of papaya strains are to be prevented. This would mean that the State should establish papaya breeding and seed distributing stations, which will have to work for the planters year after year, producing pure seeds by artificial pollination of known and fixed varieties. The principle underlying this plan is exactly the same as that of seed distributing stations in the case of cereals, cotton and the like.

Papaya plants yield harvests in twelve to fourteen months from the time of transplanting seedlings and thus bring a fairly quick return to the growers. This fact enhances the value of the crop. In the Bombay Presidency (10), the papaya tree is found to bear on an average 27 fruits per annum, with an average weight of 2·2 lb. each. The maximum yield from a single tree recorded was 104 fruits weighing 203 lb. Of course, the yield varies according to soil, treatment, climatic conditions, etc. Several important papayas, *e.g.*, Bangalore, Honey-dew, Washington, etc., have been tried at the Fruit Research Station, Hassarghatta, Bangalore. The average yield comes to about 8,840 fruits weighing 30,140 lb. in an acre plot. In this area the average number of fruits per tree was 22. At the Hawaii Agricultural Experiment Station papaya trees of 7-8 months of age yielded 28 to 38 fruits each, with their total weight varying from 19 lb. to 36 lb. per tree. The yield obtained in the Bombay Presidency and Mysore compares very favourably with those of plantations in other tropical countries. The income in money value may vary according to the marketing conditions. At any rate, this crop is found to be among the highly paying fruit crops in Western India. The life of papaya plantation can be prolonged up to ten years. But the really productive and hence economic period is only the first three years of its life. After three years it would be advisable to renew the plantations.

Yield and economic value

The proper state at which fruits should be harvested is considered to be when their stigmatic end becomes slightly yellow. When the fruit is oval and ribbed, the yellow tinge first appears on the ribs towards the stigmatic end of the fruits. The appearance of yellow tinge is the first and true indication of the full development of the fruit. Then it can be harvested and allowed to ripen in the

Maturity

Sherman (32) analysed fresh fruits and gives mud composition as follows:—

	As purchased	Edible portion					Fuel Value	
	Refuse	Water	Protein (Nx 6·25)	Fat	Carbo-hydrates including fibre	Ash	Per 100 gms.	per pound
Papayas ..	32	88·7	0·6	0·1	10·0	0·62	43	195

Work done in India on the analysis of papaya reveals the following figures:—

Name of food	Botanical name	Moisture %	Protein %	Fat (Ether Extracves) %	Mineral matter	Fibre	Carbohydrate %	Calcium (ca) %	Phosphorus (P) %	Iron (Fe) mgs %	Calorific value per 100 gms.	Carotene (International Vitamin A Unit) per 100 gms.	Vitamin B (I.U. per 100 gms.).	Vitamin C mgs. per 100 mgs.	Calories per ounce.
Papaya ripe	*Carica papaya*	89·6	0·5	0·1	0·4	—	9·5	0·01	0·01	0·4	40	2,020	..	46	11

store. Fruit which ripens on the tree turns out to be sweeter than fruit picked earlier and ripened in the store. But such fruits are likely to be attacked by the Mediterranean fly resulting in maggots, or by crows and other birds. Dropping of fruits while picking softens the injured part lessening the keeping quality of the fruits.

The papaya fruit has a very high digestive value due to the papain—a protein-splitting enzyme, which it contains. Papaya compares favourably with oranges as a source of calcium, basic ash and ascorbic acid. Vitamin C content of papaya increases with the ripeness. Average papaya is estimated to contain per 100 gms. of edible material, 2500 international units of vitamins A, 8 international units of vitamin B1, 70 mg. of ascorbic acid (vitamin C) and 33 Bourquin—Sherman unit of vitamin B2. (37). According to Daniel and Munsell (11), *Carica papaya* contains 3,000 International Units of vitamin A, 8 International Units of Vitamin B, 70 Sherman Units of Vitamin C and 33 Sherman Units of Vitamin G. (Also see pages 303, 305 and 306.)

Food value

Ripe papaya, however, is said to contain little or no papain (22). It is considered to be a wholesome and nutritious food and used at all stages of development. It is said to cure chronic constipation and piles. It is claimed to set enlarged liver and spleen right. The fruit is a valuable tonic. Ripe fruit of papaya contains about ten per cent sugar. It is used in a variety of ways. It is a highly relished table fruit for breakfast and is prepared in a number of ways into delicacies.

The general composition of the papaya fruit is worked out at the Hawaii Agricultural Experiment Station (25) and is shown by the following figures:

	per cent
Water	90·75
Protein	0·80
Fat	0·10
Fibre	1·09
Nitrogen-free extract	6·32
Ash	0·94
	100·00

Mineral constituents in edible portion of the papaya as reported by Rosedale (29) from Malaya.

Water	Ash	Cl	P_2O_5	CaO	Mg	Na	K_2O	SO_4	Fe	Cu (mg. in 100 gms.)	Mn (mg. in 100 gms.)	I (mg. in 100 gms.)
89·0	0·10	0·0036	0·007	0·004	0·00312	0·0030	0·039	0·0016	0·00126	0·10	—	0·9

The fruit flesh has been analysed by Pratt and Del Rosario (12) Thompson (34) and Adriano (1) and their average results are :—

	Flesh in fruit	Solids Total	Solids Insol.	Protein	Fat	Acids as Citric	Sugar reducing	Sucrose	Fibre	Ash	
	%	%	%	%	%	%	%	%	%	%	
Female	47	10·50	1·60	0·44	—	0·14	5·88	0·88	—	0·58	Pratt and Del Rosario
Hermaphrodite	63	10·40	1·50	0·50	—	0·15	5·82	0·07	—	0·51	Pratt and Del Rosario
	71	12·01	2·00	0·59	0·10	0·15	8·99	0·54	1·37	0·61	(Thompson)
I	70	11·19	—	1·18	0·24	—	—	—	1·66	1·22	Adriano
II	64	12·28	—	1·32	0·17	—	—	—	2·68	0·53	Adriano

Thompson (34) tabulates results on the fruit flesh of payaya at ripeness and before ripeness.

The composition at three of the dates given below shows the trend.

	Flesh in fruit	Solids Total	Solids (Insol.)	Protein	Fat	Acids as Citric	Sugar reducing	Sucrose	Fibre	Ash
Before ripening	%	%	%	%	%	%	%	%	%	%
5 months	71	6·48	3·28	0·80	0·21	0·09	2·15	0·23	0·87	0·62
2 weeks	79	6·45	2·49	0·31	0·26	0·06	4·13	0·47	0·58	0·43
Ripe	83	10·59	1·05	0·39	0·19	0·08	8·02	0·00	0·69	0·57

Fruits of a few papaya strains from Hawaii (25) have been analysed by Alice Thompson at the Hawaii Agricultural Experiment Station. Their composition is given below:

Strains	Total solids	Ash	Acids as H_2SO_4	Protein	Sucrose	Total sugars	Fat	Fibre
	%	%	%	%	%	%	%	%
Trinidad	12·14	0·53	0·06	0·43	0·74	9·72	0·06	0·78
S. Africa	13·00	0·54	0·09	0·68	0·53	10·73	0·07	0·81
Honolulu	12·20	0·56	0·07	0·50	—	10·29	0·05	0·66
Barbados	11·72	0·48	0·06	0·46	—	8·95	0·06	0·76
Panama	14·41	0·90	0·14	0·50	1·26	11·12	0·25	1·09
Tahiti	10·19	0·67	0·17	0·90	0·94	8·44	0·05	0·79

Jam, marmalade with orange rind fringes and pickle are some of the products that are made from papayas in India.

Preserves

At the Kodur Fruit Research Station, papayas have been found to be an excellent ingredient to be mixed with pineapple and mangoes in canning fruit salads. The bright colour of the pulp of papaya adds a distinctive attractiveness to the fruit salad and blends well with the golden yellow colour of the pineapple and varied tints of the mango pulp, rendering the salad very pleasing to the eye as well as to the palate.

Papaya fruits are packed in bamboo baskets for transport to local and short-distance markets in India. For

Packing

purposes of export to distant inland and foreign markets, they are packed in wooden crates, where fruits can be laid in single layers. The size of the crate may be adjusted according to the grade and number of fruits in each pack. It is found advisable for easy handling that each crate should contain not more than six fruits. Individual fruits are wrapped in paper and the interspace is stuffed with straw or softer grass to avoid injury due to shaking in transit. Fruits from Hawaii marketed in San Francisco and British Columbia are usually wrapped in paper with a packing of corrugated straw-board in between the two and then packed singly in crates holding four to six fruits each (25). Fruits which are long in shape with a small cavity and few seeds are often priced higher in the market than others. Such fruits are easy to pack and travel well. They also contain more edible matter than fruits with larger cavity. Large and thick fruits with comparatively larger cavity are generally delicate and get bruised in transit.

Papaya fruits vary in size to a very considerable extent. The shapes of fruits also differ. Some are large, some small,

Grading of fruits

some long and cylindrical, while others are oval and bulging. Fruits are, therefore, profitably marketed by grading them into different classes according to these characters. A trial at grading papaya fruits was conducted on a limited scale at the Modibag garden at Poona (6). The fruits taken for observation were of the Washington type. Larger fruits of impressive appearance were found to be always preferred by well-to-do families and for purposes of presentation.

They, therefore, commanded a much higher price than fruits sold for their collective weight. For transport to distant markets medium fruits are preferred as they can be packed well and stand transport better than very large fruits. Small fruits are easily sold to the poorer classes at cheap rates.

Storage

High temperature in storage hastens ripening of papaya fruits which may become soft at places. Low temperature prolongs the storage period to a certain extent. If fruit is picked at the proper stage of maturity it can be stored from three to four weeks in a saleable condition at 40°F to 50°F. Fruits picked and stored on these principles were sent from Poona to the United Kingdom in good condition. Wardlaw, Leonard and Babar (38) state that fruit which is yellow but firm in consistency appears to be best suited for export under storage temperature of 45°F. Such fruit can last for about twenty days. Spoilage in storage is found to be due to *Gloeosporium fusarium*.

Extraction of papain

One of the very important and economically manufactured products in commerce obtained from papaya fruits is the papain. The substance marketed under this name is the dried milk of raw papaya fruits. As it occurs in commerce, the papain is a greyish powder, which resembles animal pepsin in appearance, colour and taste. The commercial papain is not quite pure, as it is invariably adulterated with starch, bread, arrowroot, milk of white cactus, gutta-percha, boiled rice, etc. The Indian method of adulterating papain with boiled rice (10%) is considered undetectable.

The milk (latex) of raw papaya is tapped by scarification particularly when the tree is young and during the warm weather. The juice flows well in the morning. The surface of fruits is longitudinally scratched with some sharp non-metal instrument such as a bone knife or ivory piece. It has been suggested that even metal knives can be used without any ill-effect. The juice begins to flow and is collected in shallow pots held beneath. If the flow is poor, the juice may coagulate on the surface of the fruits. It is then scrapped and immediately dried in the sun or in driers. Drying under shade gives a white attractive product. Ordinary shallow pans serve as a good receptacle for the juice for drying. A suitable temperature for drying is considered to be about 100°F and the time taken may be about

24 hours. It is reported that in Ceylon, latex is extracted, stirred vigorously till coagulation, passed through a squeezer and sun dried or even dried at 50°C to 55°C in a dehydrator (8). The dried juice is used either in flakes or in powder form.

Preparation of papain deals with an important commercial aspect of the papaya crop. Papain is prepared in several tropical countries and there is a possibility of its being manufactured in Western and Southern India also. The problem at present is how to get papain of a superior quality for which good price can be had in the market. It is necessary that the method of decoloration and dehydration of the product should be properly worked out to suit Indian conditions and once for all decided whether it pays to produce papain or not. A large number of enquiries are now being made on this subject by the public. On the Baroda Agricultural Experiment Station, papain was extracted from raw fruits of the Honey-dew variety of papaya with very good and promising results. The dried milk of papaya gave a fine whitish powder, easily comparable with the commercial papain, although the former was not purified. On analysis, it was found that the Baroda product could digest 12·47 times its weight of fibrin at 70°C, while commercial papayotin digests 5·34 times its weight. The Baroda product contained 3·9% ash as compared with the pure papain in which the percentage of ash does not exceed 0·2%.

The economic importance of papain extraction in this part of India depends upon whether papain can be prepared as a by-product of papaya fruits. If papain has to displace the fruit crop by spoiling the fruits, which fetch a good price in our market at present, it does not seem to have much future. If, on the other hand, papain can be extracted from fruits which remain still saleable at a reasonable price on ripening, then it is worthwhile trying the extraction of papain on a large scale in papaya plantations. Experience on this line at Kodur has shown that the fruits that were tapped for preparation of papain lend themselves very well for canning and manufacture of candied papayas. Such fruits can also be used for the table, even though the outward blemishes may lower their fresh fruit value. Sanyal (31) estimates the yield of papain at half a pound per tree, and from his observations relating to papain manufacture in Ceylon, he concludes that "The papain

industry in India would also be quite lucrative." In Ceylon the yield of papain from an acre of papaya plantation is about 175 lb. in the first year, and later it is estimated at 100 lb. per acre. Four and a half pounds of fresh latex yield one pound of dried papain. Papain extraction has been tried at the Fruit Research Station, Hassarghatta. It is observed that 100 lb. of long fruits yielded 171 grams of crude papain. The yield from long fruits is higher than the yield from round fruits.

Ceylon at present holds the monopoly of export of papain to Europe and America in large quantities. If better methods of extraction and preservation are evolved and means of keeping the colour of the product white, are found out, India can expect to compete with Ceylon in the export of papain to those countries even though the higher cost of cultivation in most parts of India may be a handicap.

It is observed that East Africa has a prosperous papain industry developed around Arusha on the slopes of Mount Meru and Moshi.

The exports of papain from Colombo are given below:—

			Quantity lb.
1932	..	..	64,356
1933	..	..	100,046
1934	..	..	103,778

The price of Ceylon papain during the years 1930, 1931 and 1932 was 7 shillings, 5 shillings and 6 pence and 5 shillings and 3 pence per lb. respectively. But the price fell as low as 3 shillings and 9 pence per lb. in 1933 and again rose in 1934 to 6 shillings and 9 pence. This serves to give a comparative idea of the ruling price and extent of fluctuation.

Diseases and pests of papaya

Papaya is free from many serious diseases so common with other fruit trees. However, stem-rot (24) sometimes causes considerable damage to this crop. It is caused by the fungus *Phythium aphanidermatum* which is soil-borne. The symptoms of the disease are that the trunk of the tree rots at the collar (the point where it touches the soil or where the root ends and the stem commences), and the leaves wilt. Water-logging

is the chief contributing factor, as the fungus thrives well under such conditions. Scraping off the affected parts and smearing coal tar, Bordeaux paste, and dilute carbolic acid were tried at Kodur (Madras) to combat this trouble but with no appreciable effect. Further light requires to be thrown on the control of this disease. It can be checked by preventing water stagnation at the roots, which is the best preventive measure against this disease.

Of insect enemies of papaya, red spiders are the most important. Red spiders or mites are sometimes found on the surface of ripe fruits or leaves. The leaves turn yellow and the fruit becomes roughened with brownish colour when attacked by mites. Dusting with sulphur or spraying with lime sulphur is an effective control.

Rejuvenation

When papaya trees attain a large height so as to make harvesting difficult, the trunk may be cut off at about three feet from the base. This induces a large number of buds to sprout, of which only two or three are retained, the rest being removed. These sprouts ultimately become bearing trees. This system is practised to a small extent in the districts on the West Coast of Madras Presidency.

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CHAPTER VII

GRAPE (*Vitis Vinifera* L).

Introduction

The grape although limited to a small acreage, is a highly specialized crop in the Bombay Presidency. The climatic conditions of the Deccan are not very suitable for the cultivation of choice varieties, but due to equable temperature, the vines bear fruit during winter and the fruit is available for sale in the months of February to April, when the superior table grapes produced in the countries to the North-West of India are not on the market. An equable climate and off-season fruiting are, therefore, the factors which encourage grape cultivation in this part of the country. But whenever the temperature reaches the freezing point, considerable damage is caused to this crop. Frequent losses due to frost during the last decade have undoubtedly checked and discouraged the extension of grape cultivation. As stated above, the quality of grapes grown in the Bombay Presidency is not very superior, and this fact retards to a certain extent its extension in acreage. Nevertheless, its cultivation affords a very intensive kind of farming, and if a full crop is harvested, it gives a fairly good income to the grower. It is principally on this ground that the importance of grape is recognised.

Origin and distribution

It is difficult to locate the original home of grape vines, but it appears to be a native of Asia having originated in the Caucasus regions. According to Alphonse D'Candolle (29), records of the cultivation of grape vines in Egypt go back to 3,000 to 4,000 B.C. Viticulture was flourishing in Greece in the time of Homer. Grapes are widely grown in several countries of the world. They grow almost in all countries of Europe, United States of America, parts of Africa, Queensland, South Wales, Palestine, Persia, Afghanistan, South of China and Brazil. Ninety per cent of commercial grape culture in the U. S. A. are centered on the Pacific coast, where European varieties are grown for the production of table grapes, raisin and currant grapes and for wine purposes. In the rest of the country, hybrids and native grapes are grown.

In India grape growing is restricted to Kashmir, the Punjab, the Deccan and the Madras Presidency.

Baluchistan in Pakistan with an acreage of 2,429 under grapes, supplies table grapes to almost the whole of India from September to December. Raisin grapes are also obtained in large quantities from Afghanistan, North-West Frontier Province and Baluchistan. In the Punjab, viticulture has not yet taken a real foothold, but a few early varieties bearing crops before the advent of the monsoon appear to be gaining some popularity. Formerly, inferior varieties like *Tas*, *Tor*, *Sursavi*, *Spinsavi* and shy bearing *Kishmish* and *Bedana* were the main cultivated varieties in the Punjab. Muscat and Sultana seedless introduced from Australia had also been tried only with uncertain results. Even the introduced early varieties are subject to considerable damage by periodic hail and dust storms and premature rains during the harvesting season. In South India an inferior variety of grapes is grown fairly extensively in Michaelpatti and Vellodu in Madura districts and Krishnagiri in Salem district and in and near Bangalore. During the last decade the seedless Kishmish was introduced to South India and has acquired an unexpected popularity under a most intensive and distinctive method of culture.

In the Deccan, grape is grown chiefly in the districts of Nasik, Poona and Ahmednagar. The total area under grapes is 964 acres in the Bombay Presidency. Most of the acreage is confined to the Nasik District. There are several other tracts such as the Nira right bank canal, Sholapur and Bijapur where grapes can be grown in this Presidency. Grape cultivation has been recently introduced into Gujerat tract also with fair success. The acreage of grapes in India is as follows:—

Bombay	.. ..	964 acres
Madras ..	.. ..	350 ,,
Hyderabad	.. ..	100 ,,
Mysore	.. ..	50 ,,
Total	..	1464 acres

Grape belongs to the Natural Order *Vitaceae*. There are three broad horticultural groups under which all

Varieties and their classification

the cultivated types of the genus can be classified. They are:—

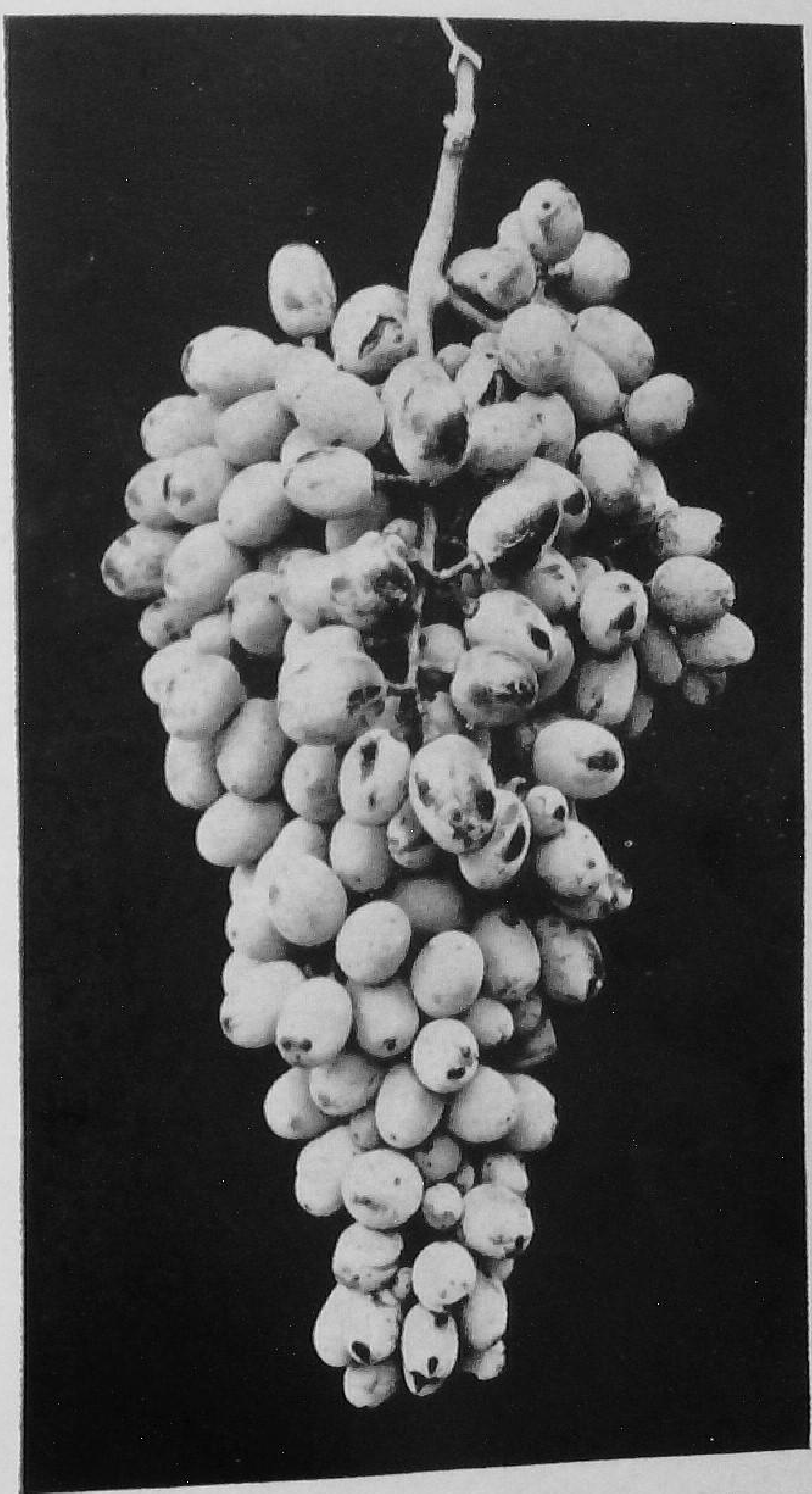
1. *The table grapes*, such as *Fakdi*, *Bhokari*, and *Kali* and *Pandhari Sahebi*.
2. *The raisin and currant grapes*, such as Sultana and Thompson Seedless.
3. *The juicy grapes*, such as Muscat and Black Prince, which are principally used for making wines, bottling fresh juice, etc.

The table grapes are either large or medium sized, black, greenish white or pinkish in colour and are sweet with but few seeds and a thin or thick skin.

The raisin grapes are large, medium sized or small berries. They are black or greenish white in colour. They may or may not have seeds. They have a high percentage of sugar and have either thin or thick skin. All raisin grapes grown in the U. S. A. are produced in California. They were first introduced there in 1851. Some of the varieties are Sultana from Spain, White Corinth and Red Corinth from Crimea and Alexandria. The fruit of Alexandria variety ripens in mid-season and its colour is yellowish green. The bunches are long and loose. It has an attractive appearance and a peculiar flavour. Sultana can be grown without irrigation but to get good fruits, irrigation is necessary. Thompson Seedless is closely allied to Sultana. All these varieties have large bunches, with medium sized berries of good quality.

The juicy grapes are either black or whitish. They have a strong aroma which is a distinct character. The sugar content is high and the juice is slightly acidic. They are chiefly used in making wines. All the juicy types such as Muscadine fall under this group.

European or vinifera grapes (*Vitis vinifera*) form 90% of the cultivated vines in the world. Stress has been laid in some countries on breeding work to evolve suitable varieties, better adapted to local conditions in tropics.



BUNCH OF BHAKARI VARIETY OF GRAPES.

Facing page 318.

Grapes in the Bombay Presidency are chiefly consumed as fresh fruits. Their cultivation is very limited and there is no drying, bottling or wine making of grapes in this part of India. The following are the chief varieties grown here.

The *Bhokari* is a common variety grown on a commercial scale in the Bombay Presidency. It is the highest yielder of all the local varieties and is, therefore, the chief commercial variety. Its vine grows vigorously and has a round stem. It has a red pigment on young shoots and veins on leaves. Leaves are deeply lobed and dentate. The basal leaves have wide flaps, curving away from the leaf stalk. Bunches are large, compact, long and tapering. The central portion of the bunch is cylindrical while the upper part is thinly shouldered. When fully ripe, the berries develop a faint rosy bloom and become large and round. The skin of berries is thick and leathery. The pulp is luscious and acid sweet in taste. The texture of the pulp is soft and watery. Seeds are hard to chew. Berries do not keep well for long. The cultivation of this variety is concentrated at Nasik and scattered in other areas.

Next to *Bhokari*, *Fakdi* is the most important commercial variety in this Presidency. The *Fakdi* vine is the most vigorous of all the varieties grown in Western India. The main characteristics of this variety are that it has a thick flat wood with the basal portions and trunk of ripe canes flat and grooved. Its yielding capacity is lower than that of *Bhokari*, but in a favourable season it can compete with the latter. *Fakdi* yields a quality of grapes superior to *Bhokari*. *Fakdi* leaves have shallower lobes than those of *Bhokari*. The segments at the base have narrower flaps, which do not curve away widely from the leaf stalk. Bunches are very large, loose, irregular and heavily shouldered, being often wider than long. They are usually smaller in size than those of *Bhokari*. The colour of berries is watery green, and develops a bloom when ripe. Berries are oval in shape. The pulp is soft, sweet and watery. The skin is thin and soft. *Fakdi* is not a good variety for shipping or for long transport, but being very sweet in taste, it fetches a better price than *Bhokari*.

Pandhari Sahebi makes slow growth in Western India. The trunk and the canes are slightly flat. The canes are thick stout and short. This variety is partially self-sterile and hence a shy bearer. Its leaves are large and rough. Leaf-stalks are stout,

having prominent veins with rounded teeth. Bunches are usually loose, most of the berries are "shot grapes" with no pips inside, owing to the imperfect pollination. The shape of pollen grains is irregular. This variety is grown along with *Bhokari*, which is a self-fertile variety. The colour of berries of *Pandhari Sahebi* is whitish and develops an amber bloom when ripe. Owing to the attractive colour of its bloom and the high quality of berries, it is called *Pandhari Sahebi* (white big grape). It is a suitable table variety of grapes grown in some parts of the country for distant markets as its keeping quality is relatively high.

Kali Sahebi (black big grape) is a dark purple variety, and is a vigorous grower. Its yielding capacity is low. Leaves are dark green with deeply incised margins. The lobes are compact, long and broad at the base, and very heavily shouldered. Berries are long in shape, thicker at the base, cylindrical and slightly drawn in, in the middle, and distinctly flattened and depressed at the stigma end. All berries do not ripen simultaneously. It is a late variety requiring about fifteen days more to ripen than *Bhokari*. It is green when raw, but turns dark purple when ripe. Its pulp is firm and sweet in taste. The skin is thin. It stands second only to the *Pandhari Sahebi* in keeping quality. Fruit stalks are slender and weak, which makes the berries drop while picking and packing.

Kandhari vines grow vigorously in the Bombay Presidency. The upper side of leaves is dark green while the veins on the underside are reddish. Leaf margin is serrated. Basal lobes are slightly inside, over-lapping and somewhat hiding the leaf stalk. Bunches are of medium size, very compact and rectangular in shape. Berries are of medium size, thick-skinned, sweet and dark purple when ripe.

Black Prince is an early variety. It grows vigorously, yielding a prolific crop which matures earlier than that of other varieties in this part of India. The wood is thin, round and short-jointed, having short canes. Leaves are greenish yellow in colour. Bunches are of medium size, with many "shot grapes", cylindrical and pendulous. Berries are of medium size, thick-skinned, highly aromatic and sweet. When fully ripe, the berries assume dark purple colour. Berries do not ripen simultaneously. This variety is not grown on a commercial scale.

Neelum is a variety of inferior quality. Its leaves are thick,

tri-lobed with the lower side thickly covered and with white pubescence. It is a slow and shy sprouter. Bunches are small, compact and cylindrical. Berries are dark purple, round and small, with thick skin and acid taste. Berries ripen earlier by fifteen to twenty days than in the case of other varieties.

Soil

An ideal soil for grapes in Bombay Presidency would seem to be a loam with good drainage. Vines grow very vigorously when the soil is loose and has perfect aeration. However, the grape is being grown on a variety of soils with fair success, provided such soils are well drained. In the districts of Poona and Nasik, grape vines are growing on black, medium black and shallow light soils, which have murum as sub-soil. In the Punjab and Sind, any soil is considered suitable for vine cultivation if it does not contain a high percentage of harmful salts. The depth of soil is not considered in this Presidency as important, as the roots of vines generally do not penetrate very deep, not beyond about three feet ordinarily in Deccan. *Chopan* or clayey soils as well as those having a hard substratum are not selected for vine growing. Lagatu (51) and others mention that "The addition of large amounts of potash is necessary initially to replenish the potash deficiencies caused in the soil, selected for grape vines." Chauzit (21) is of the opinion that the yield in grapes increases in the proportion of sulphur used. The effect of sulphur is pronounced if there is a large quantity of organic matter in the soil. The amount of sulphur used is 200 kgms. per hectare. The most dominant plant food of vines is said to be potash. Granite soils are rich in potash and felspar, and, therefore, they produce grapes of excellent quality. Soils rich in lime are very suitable for table grape. Grape vines are among the most resistant to soluble salts in the soil. They are found to grow well on soils containing 77 parts sodium chloride out of 286 parts of total salts per 100,000 parts of water.

In Baluchistan a hard black soil is preferred for Speen *Kishmish*, a hard reddish soil for *Haita* and a sandy or gravelly soil for all other kinds of grapes. The soil used for grape growing in Nasik is a medium black soil with a lime content of from 3 to 5 per cent. In South India, the maximum success has been achieved in soils which are very open and gravelly. Such soils have a perfect drainage and being hungry, they respond magnificently to care.

Climate

Climate is an important factor influencing the cultivation of grapes. A close study of the climate of grape growing tracts in different parts of the world shows that as far as possible, it must have a warm and rainless summer, during which the ripening of fruits takes place. Heavy and long continued rains also affect the keeping quality of the fruits. The ripening period should follow a good period of resting, during which the vines are fully or almost completely leafless. Lack of such conditions makes grape cultivation uncertain and risky and tends to lower the quality of fruits produced. In the heavy rainfall districts of the Bombay Presidency, grape vines make a poor growth, which, coupled with the local practice of pruning them twice a year, retards fruit bearing. It is observed after many trials in the Konkan and the Karnatak that grape vines do not yield profitable crops in heavy rainfall tracts. In such places, they bear a few bunches of rather inferior quality of fruits and are prone to a serious attack of mildew and anthracnose diseases. Tracts like Bijapur, Sholapur and the Nira right bank, where rainfall is not heavy and the climate is dry, are suited to grape vine cultivation, if the soil is suitable and if there is enough irrigation facility.

Because of the equable climate, grapes in the Deccan and South India do not enjoy a long dormant season as in the leading vine growing regions of the world. The relatively long periods of growth and the absence of a prolonged resting period, render grape vines and their crop open to serious damage by frost, which though uncertain occurs once in a way in Western India. In the grape growing regions of South India, frost, dust and hail storms are practically unknown, but despite this fact, the quality of fruits produced is low. It remains to be seen if the introduction of better varieties or the breeding of varieties which combine the hardiness and productiveness of indigenous types with the quality of choice exotic ones will be profitable. The very useful character associated with South and West Indian viticulture is maturing of crops in a season, when grapes from Northwest of India and Baluchistan are scarce. The wide popularity enjoyed by grapes throughout India, render breeding investigations and extensive orchard trials with imported varieties certainly worth while. Sind and the Punjab have a warm summer, but occasional rains, dust and hail storms occur

just at the time when the berries develop seriously damaging the crop. Northern India does not therefore present a suitable climate for the cultivation of choice varieties of grapes. Winkler (84) points out that climate affects the quality of table grapes. He finds that in cool seasons, acidity is relatively high in relation to sugar contents, and in hot seasons it is relatively low. Dry weather at the time of ripening is very helpful and favours the preservation of fruits.

Propagation

Commercially grape vines are propagated by cuttings of eight to ten inches length, taken from fully mature wood of about six months of age. In the Bombay Presidency cuttings are prepared in the month of October when vines are pruned for the sweet crop. Canes with moderately short internodes are chosen for taking cuttings from their mature basal portions. Bioletti (10) suggests that a good cutting should consist exclusively of healthy one-year old wood, and should have been taken from vines that have borne heavy, but not excessively heavy crops. Young vines generally produce immature cuttings, while abnormally heavy producing vines possess mostly ill-nourished cuttings. Bioletti and Jacob (13) have found that the popular belief that large sized cuttings produce larger vines is not correct. Though the influence of the size of cuttings was marked in the beginning, later in the vine yard, it largely disappeared. Winkler (82) has found that oxidising agents hastened callus and root formation and improved the rooting of grape vine cuttings. Quinn (66) states that the nature of the season affects the striking of roots in cuttings. The temperature favourable for this appears to range from 50°F to 53°F in the soil at the base of the cuttings.

Cuttings are planted in October in the Bombay Presidency, in beds in a slanting position and are allowed to remain there till the following January, when they are transplanted in the field. During this period of three to four months, cuttings strike a fairly large number of roots and are ready to be successfully transplanted. Vines can also be propagated from seeds, but owing to the variations produced in seedlings, seed propagation is adopted only for breeding and selection of desirable types. Woodfin (86) states that some settlers have successfully introduced the method of grafting vines in New Zealand. They plant cuttings meant to serve as rootstocks in their

permanent positions with the scion wood planted nearby between rows of rootstocks. Grafting is done when the rootstock cuttings start growing. "Over-grafting" or top-working of American varieties is practised in the vineyards of some countries. This method is used for converting inferior varieties into better ones. Some varieties of American and hybrid (American-European) grapes are more or less resistant to the attack of the phylloxera trouble. Though they may not all be immune to its attack, their root system is hardy enough to withstand the effects of the attack. So, wherever the attack of phylloxera is feared, these resistant varieties are recommended as rootstock plants for grafting upon. Budding and grafting of grape vines are also resorted to in some countries, where certain undesirable varieties require to be replaced by better ones. However, budding does not appear to be extensively practised.

A method known as bud-graft or *yema-graft* is also in use in Spain, Italy and California. It is a form of side graft, in which the scion is a single bud with a piece of wood attached to it and joined to the rootstock from which an equal piece of wood is removed previously. Whip, cleft and side grafting with long scions are also practised on a small scale, especially on old vines with scions of past season's growth. Bench-grafting is also possible with grape vines. Bioletti (8) found that bench grafts of vines callus best in sand containing five to ten per cent of moisture, and they are more successful than other methods of grafting. Grafting is a profitable practice, where it is not possible to get a good crop from own rooted plants due to the attack of phylloxera or other causes. So far no necessity has been felt to raise vines by grafting on disease-resistant rootstocks in Western India. Layering is also used in propagating vines and is useful in filling gaps in the orchard, as it gives larger plants. Propagation by single-eye cutting is a useful method too, where a valuable variety is intended to be multiplied. Layering vines of all ages upto hundred years of age is found possible.

Preparatory tillage and planting

Before planting an area with grape vines it is essential to till the soil properly and to add humus to it. Thorough deep ploughing and the application of a good dose of farm yard manure to the soil is considered necessary. Ploughing in *sann* hemp (*crotolaria juncea*) as green manure prior to the planting season is recommended.

Pits of 1½ ft. by 1½ ft. and 1½ ft. are taken at eight to ten feet apart. They are filled with the original soil mixed with about twenty pounds of old farmyard manure. At times a small quantity (2-3 lbs.) of oil cake is also applied to each pit. In some parts of South India, the pits are filled with alternating layers of green leaves and tank silt until flush with the ground level. Occasional watering is done to the filled up pits to facilitate decomposition of the green leaves prior to the planting of the vine. In some places a small amount of bone meal may also be added with the green leaf. Rooted cuttings are then planted singly or two or three of them being used together in each pit. Grape vines, being very susceptible to white-ant attack in the early stage of growth, it is advised not to add any manure, especially the farmyard manure, to the pits at the time of planting in localities where the attack of white ant is feared. In fertile soils, it may not be necessary to add any manure to the soil till about a year after planting.

Planting is done during the month of January in Western India. It is essential to give a support to the vines in each pit, immediately after they are planted in the field, as explained later. The sprouts which shoot from side buds are rubbed off, and the vines are usually allowed to grow into single canes. Care is necessary in handling the vine roots at the time of planting. Roots of young vines are tender and may be jammed or injured at the time of lifting. All such injured roots are trimmed off at the time of planting and the healthy ones are shortened. The top is pruned to a single cane when only one cane is desired to be retained. The cane or canes that are retained have to be cut back to two or three buds or eyes, soon after or prior to planting. This pruning is essential where vines are to be grown by any of the American methods of training and pruning described elsewhere.

Instead of rooted cuttings, only the cuttings taken from the winter prunings are commonly used for planting in some places in South India. Such cuttings rarely get damaged by white ants and grow vigorously in the rich media inside the pits, due to the rich mixture of green leaves, silt and bonemeal applied some month previously and well decomposed by the time cuttings are put down.

In California, the distance of planting varies from eight to ten feet, the former spacing being more prevalent. Greater space is provided in raising plantations, in which case even fourteen feet spacing between vines is not unusual. A few rows of vines are left out here and there to provide avenues for convenience of access to the vineyard. In parts of Central and Southern Europe, grapes are planted on hill slopes with a spacing of only 2 to 3 feet.

Training of vines

In the Deccan the support generally given to vines soon after planting is some kind of temporary stick planted near the base of the vines. When the vines begin to grow large stemcuttings of *pangara* (*Erythrina indica*) are planted in the monsoon which strike roots and replace the wooden sticks originally given forming a permanent support to the vines. If *pangara* stems are not available, wooden stakes can be substituted for them or trellis may be prepared to train vines upon. *Commiphora beryii* is the most commonly used live stake in Madras Presidency. Several systems of training vines have been tried in the Deccan. The single-stake or *pangara* system is, however, the most commonly adopted one. It consists of planting vines eight or ten feet apart, and when they have grown to a height of six to seven feet on the temporary sticks they are headed back to a uniform height of five feet. Only three or four lateral spurs are allowed to grow just below the point of heading back, all those below them being nipped as soon as they sprout from time to time. The spurs thus allowed to grow form later on the main lateral branches, and bear fruits. The shoots are periodically pruned to encourage fruiting as described elsewhere.

Single-stake system

The Junnar system is named after the place Junnar, where it was originally practised. In this case, four vines are planted in each pit. Pits are eight to ten feet apart. While training them, four stakes are planted at the four corners of the pits, and a vine is trained on each of them. The heading back, growth of spurs, pruning and the like are all similar to those of the single-stake system. The chief difference is that there is more crowding in the plantation, which considerably hinders cultural operations and adds to the cost of cultivation. This system also requires more stakes for support.

Junnar system

In the case of the bower system, vines planted eight feet apart

are trained on posts connected by poles crosswise at a height of five to six feet. As in the single stake system, vines are led to the cross poles without allowing any lateral growth. They are headed back at the height of the cross poles, and lateral shoots are allowed to grow on them as desired to cover the top of the frame work, making a bower. Pruning or trimming is done from time to time. Adjacent vines meet one another and spread out on the bower leaving free scope for cultural operations below.

Bower system

The bower or over-head system is quite popular in all parts of India, wherever grape vines are grown in bungalow compounds. The frame work is built of strong wood of good quality, and pillars are also constructed in brick and mortar to give additional strength. Vines are allowed to ramble over this structure providing a neat shady corner, after they have spread over the entire bower. This method of training is very expensive from the point of view of the commercial grower, but has much to recommend it for the backyards of houses as it provides a fine vineyard involving little labour and expense except during the first one or two years. The vines trained on the bower also provide a cool and delightful sitting place for the members of a household.

Umbrella system

The umbrella system consists of training vines on to a frame work built in the shape of an umbrella. The vine rows trained by this method almost amount to bowering, except that every vine has its own bower and is independently supported.

Trellis and Kniffin systems

The trellis and Kniffin systems are those in which vines are trained to horizontal wires stretched one above the other at a height of two feet, four feet and six feet or so from the ground and supported on posts planted ten to fifteen feet apart in the row. Once the vines have fully extended, regular pruning for fruiting is resorted to.

Low-head system

In some parts of the Punjab, vines are headed back to a height of two or three feet from the ground, when a few laterals are allowed to develop. In course of time the main stem gets thick and strong and can stand up erect without any support. Low headed vines raised in this manner save the cost of supports and are easy to be sheltered

from frost damage. But they are also an easy prey to jackals and other pests, where such pests are common.

The Junnar and single stake systems were compared for yield in the Ganeshkhind Fruit Experiment Station, Kirkee. The variety under trial was *Bhokari*. The vines trained by the single stake system yielded four pounds and thirteen ounces each, while those trained by the Junnar method yielded seven pounds and five ounces of fruits per vine. But the single stake system was found to have several advantages, such as free scope for cultivation by bullock power instead of man power and easy irrigation. From the point of view of orchard practices, the single stake system, where vines are planted squarely is thus a superior method of training. It is cheap and makes cultivation economical. The spraying of vine is also easy. Training of vines on trellis work requires a good deal of capital investment for buying posts, wires and other materials, and the cultural operations cannot be carried on crosswise. The overhead or bower system involves a large investment to start with, and it is difficult for pruning and spraying. The choice of training method is, however, a matter of individual taste and resources, and under certain conditions one method may be more remunerative or suitable than another.

Relative merits of training systems

In South India vines are trained to grow up to a height of four to five feet from the ground without any side shoots and on the support of a live stake—*Commiphore beryii*, and the canes at this height are allowed to ramble over a specially erected structure made of dry wooden or bamboo poles, built at times with considerable care and at high cost. In parts of the North-West Frontier and Baluchistan, a similar but cheaper system is prevalent, but instead of training the trunk of vines to grow erect, they are allowed to reach a small and low platform made of dried branches, roughly at an angle of 45°. The platform is constructed between every two rows of vines, at a height of two to three feet from the ground level, and canes of vines from both the adjacent rows are made to spread upon this. If more than two trunks are grown at one place, roughly half the number is made to trail their canes on the pandal (wooden structure for training grape vine) on one

Training in South India

side, and the rest to do so on the opposite side. Both the above systems involve an annual recurring expenditure for the construction or repair of pandal, and also render the cultivation of the vineyard by bullock power difficult, if not impossible.

Training system in U. S. A.

The technique of training and pruning of grape vines has received a great deal of attention from American workers. The number of varieties grown in American vineyards is so numerous (30), and their varietal peculiarities regarding growth and fruiting habits are so varied, that it has been found necessary to devise the best system of training and pruning for each variety under cultivation. Bioletti (12) has shown that the training and pruning methods adopted in all systems of viticulture can be grouped under the following three heads:

(a) Vase form, (b) Fan shaped or trellised,
(c) Cordon form.

As pruning methods are intimately associated with the training systems of vines, the two aspects are described together here.

In the case of vigorous growing varieties like Tokay or when vines are grown on a rich soil, the head pruning to a vase form is said to give the best results. By this method, a few spurs are retained on each vine at a height of two-and-half to three-and-half feet from the ground level. The spurs are distributed on arms all round the head, at suitable distances. Pruning to short spurs on a medium high trunk, is popular for varieties like Muscat, which bear on lower buds. For vigorous table grapes, which do not bear on short spurs, like *Malaga*, very long spurs have to be retained. For Sultanina, head pruning is recommended, but unlike in the abovementioned varieties, long canes have to be retained. Sometimes these long canes are curved to form a semi-circle when tied to the stake, while in others the canes are spread so as to present a fan-shaped head when tied to the stake. The latter method is said to be largely used for Thompson Seedless. The single vertical cordon system of training involves the growth of one trunk, around which a large number of short spurs are allowed to grow on all sides, from a low part of the trunk up to the top. In unilateral cordon, the trunk is bent at a certain height and allowed to trail over a horizontal wire or other support, and short or long spurs are distributed over the entire length of the

canes on the horizontal support. In bilateral cordons, the trunk is allowed to branch into two at a certain height, and thence allowed to trail along the horizontal supports in opposite directions. In the Kniffin system, the bilateral cordon is formed on the same vine at two different heights.

Head pruning or vase or goblet pruning is perhaps the most popular method in commercial vineyards in other countries. The trunk in this system should be vertical, smooth, straight and sufficiently high. The head should have arms starting as nearly as possible from the same level, and the number of arms should be sufficient to furnish the spurs necessary for the production of a good number of bunches.

Since some vines are not fruitful on the lowest two or three buds of the cane, it is necessary to adopt long cane pruning in their case. Fewer canes are retained on each vine by this system of pruning. It is necessary in this system to prune some spurs to two buds, so that these may grow into bearing canes in the succeeding year. These are, therefore, called "renewal spurs."

The characteristic of cordon pruning is that the vine is given a much longer trunk than in the other two systems. The trunk is not vertical, but rises in a gentle curve to a certain height and then extends horizontally to the next vine. It is suited to vigorous varieties of table grapes, which produce large berries and large bunches.

There are numerous variations and combinations of these three main systems of pruning and training vines. Bioletti (11) states that seedless vines are vigorous growers and need long cane pruning and trellising. Sefick and Clark (71) observe that pruning grape vines according to the Kniffin system was found to be the most satisfactory method in Tennessee and other States. The trellis consists of two wires, 30 and 60 inches above the ground. The pruned vine is composed of a single permanent trunk extending to the top wire and a one-year-old cane trained in each direction on each wire. Summer pruning is not recommended.

Pangara trees provide a good support in the single stake system. Large stem or limb cuttings of about six feet in length are planted near the vine on the leaward side about the commencement of the rainy season. If it requires to be replaced, it should be done in the month of

Pangara stakes

May. The top cut should be painted with liquid coal tar. *Pangara*, being a live support, should be irrigated liberally, and it grows well when once established. Special attention should be paid to the pruning of *pangara* trees, so that they remain within limits and do not outgrow the vineyard. When pruning, a tuft of leaves should always be retained at the top to nurse the *pangara* stem. Borers often take shelter under the *pangara* bark, and care should be taken to remove them and treat the trees with tar or by other means. The root system of the *pangara* is scanty, and hence this tree does not compete with the root system of the grape vine to any great extent. Pruning of *pangara* growth is usually done along with vine pruning.

Pruning of grape vines

In the Deccan, the first pruning of vine is done four months after planting, that is, in April. This is the time when the height to which the vine trunks are to grow is decided upon. A height of five feet is considered convenient. Most growers do not allow side shoots to grow from vines below this height. The present tendency amongst a few growers, however, marks a deviation from the longstanding usage. They allow the vines to grow to a height of about eight to ten feet, and encourage the growth of side shoots from about two feet above the soil. The advantage of such a method is difficult to accurately gauge at present, but it appears to be a mistake to allow such a large number of branches on the vine as they are likely to reduce the bunch size and perhaps also lower the quality of fruits. These spurs grow and form canes for the October pruning. The second pruning is given in the month of October, that is, six months after the heading back of the vines. At this time, the vine may have three to four canes growing in a head. These canes are pruned "forward", that is, leaving three or four buds at the base. Of these, one or two buds at the end sprout, and bear fruit bunches. The lower buds remain dormant. Thereafter, the vines are pruned regularly in April and in October.

The April pruning is done after the harvest is over. Canes are cut back to the foundation, and only one out of the three or four original buds is left on the canes. If any cane is weak, it is cut back without leaving any bud at all. April pruning is called "back" pruning, and is done on the same spur as was pruned in the previous October. Thus the end part of the stump

left in October, together with all new growth is pruned away in the following April. The lower bud or buds which remained dormant after the October pruning, now come to activity and forms the new canes for pruning in the next October. The heat during the month of May induces the growth of shoots into vigorous sprouts, provided irrigation facilities are available. Irrigation, however, is not given for two or three weeks after pruning, depending upon the condition of soil at the time of pruning. Some growers do not give any manures to the vines at the time of April pruning. But it is observed that the application of manure and regular irrigation are necessary to get strong canes. The growth of canes after April pruning is an important factor in getting fruiting spurs after the following October pruning, and influences the year's crop materially.

Precautions to be taken at the time of pruning against mildew and other diseases are discussed later. At the time of the April pruning, irrigation is stopped for two or three weeks to check further growth of canes. The canes are then pruned back as already explained. The soil is then ploughed deep, a heavy application of manure is given, and the first irrigation is allowed about three weeks after the vines are pruned. Some growers defoliate canes about three weeks before pruning, and irrigate vines at the time of pruning. Experimental evidence as to the benefit of defoliation and irrigation at the time of pruning is lacking. It is believed that canes mature well when they are defoliated and exposed to the sun, and buds develop vigorously when they are irrigated before pruning. Defoliation undoubtedly facilitates pruning.

In the case of raisin grapes, three methods of pruning are recognised, namely, spur (stool or short) pruning, long or cane pruning, and spurring laterals on canes.

Winkler (83) states that "The retention of the larger parts of the yearly growth on the vine combined with some method of thinning offers promise for improved quality and yield in many table grape varieties." It is necessary to know what kind of pruning is suitable for a given variety. Some varieties like the Sultana produce fruits from the fourth bud from the base of the cane. In this case short pruning is not desirable. This variety has a tendency to send out suckers, water sprouts and sterile shoots. There is another school of thought, according to which

no pruning is necessary to induce vines to fruit, specially when they are grown for the production of ordinary wine. Unpruned vines are seen bearing good fruits in Kashmir and several other tracts in India. "The main objects of pruning are to give the vines a suitable form and then to conserve this form and secondly, to regulate the bearing in such a way as to obtain the quantity of fruits for a number of years at the minimum expense" (1). Winkler's (83) experiments on vine pruning have established that non-pruned vines produce more fruits and of better quality and normal sugar contents, and that pruning decreased germination power of pollen grains.

Pruning seasons

Amongst some growers, there is a tendency to prune their vines out of the normal season, with the idea of getting fruits at a time when the normal crop is out of the market. On the whole, it is very risky to depart from the practice of pruning in the proper season. A close study of the weather conditions in the Deccan shows that, the first two weeks of April and October give sufficiently warm weather to induce quick sprouting of spurs. Pruning in May or June or September and November, or in months other than the usual time, does not give a proper warmth required to induce normal sprouting of buds. It is, therefore, necessary that both the April and October prunings should be practised in their proper seasons in order to get a satisfactory crop under the Deccan conditions. It is, however, found that off-season prunings may be profitable under certain conditions, as when the temperature is low and rains delay sprouting, as a result of which the canes do not grow properly and do not bear satisfactorily. Off-season would also be advisable when low temperature or such other factor causes injury to the vines. The frost causes injury usually in the months of January or February at the height of winter. In that case vines may be pruned in the months of February or March and allowed to grow till the end of September when they can be pruned again for the October growth. Pruning in the months of February and March under such conditions is but natural. But no crop can be expected during the usual season of November to April under such circumstances. In the Madras Presidency, particularly in the southern districts, vines can be pruned in December-January and April-June, *i.e.*, after the harvest of the crop is completed. In California, on the European con-

tinent, in the North-West Frontier Province, Baluchistan and the Punjab, pruning is done only once a year during winter or at the commencement of spring. Vines remain in a leafless and resting condition throughout winter. Due to low temperature during winter, the disease causing organisms, like anthracnose and mildew do not thrive. Observations have been made in the Deccan to see the behaviour of canes when the April pruning is dropped. Every care was taken to keep the vines free from disease. But during the monsoon a good deal of sprouting occurred, and after the October pruning, the new spurs did not make a vigorous growth as would have been expected under normal conditions.

Girdling and nipping

Girdling is sometimes practised to induce heavy bearing in grape vines. "The process of girdling consists of making two parallel incisions through the bark around either the trunks, arms or canes of the vines, and of removing the bark between the two parallel cuts. This must be thoroughly and cleanly done while the vines are in bloom" (38). Jacob (48) recommends that a complete ring of bark, $\frac{3}{16}$th of an inch to $\frac{3}{32}$th of an inch wide may be removed from the stem of Thompson Seedless and Corinth. Girdling can be practised for several years to get successful crops, provided the soil is good and the cultural practices are adequate. Bioletti (12) suggests that ringing should be $\frac{1}{3}$ to $\frac{1}{4}$ inch wide and should not penetrate the wood. It is done to increase the size of the fruit and hasten ripening. He, however, states that ringing is a weakening process, excepting in Black Corinth (syn. Zante Currants), which hardly bears any crops without ringing. Girdling is a necessity in the Zante Currants which otherwise shed fruits shortly after blossoming. The trunk of these vines is girdled by removing a bark $\frac{1}{8}$ inch wide in Australia, while other vines resent such treatment, and have to be girdled on the limbs. Some writers recommend wrapping of some kind of cloth or a surgical adhesive tape round the girdle to induce quick healing of the wound and it is also stated that "ringing affected before the flowers appear, towards the base of the branch will further increase the number of leaves and fruits". It is advised that ringing should never be done when the clusters are partially in bloom or in the

middle of the blooming period. In case of rank growth and subsequent failure of crop, tipping of vines may be practised. It does encourage the growth of laterals. On flat soils of clayey texture, where good cultural manurial practices are followed, it has a tendency to make foliage short, close and dense with laterals at every bud down the cane length, and each has a tendency to run away, if not arrested by the knife. Ring barking can be done to obtain early ripening, and should be done when the berries are half grown. A much higher sugar content and lower acidity were observed in the ringed than in the unringed grapes.

After the April pruning the land is ploughed between the rows of vines and cultivated. The soil near the roots of vines is removed to a depth of about a foot in a circle with a radius of about three feet from the vines. The smaller roots are thus exposed and pruned. In about ten days the usual dose of manure is added to the original soil taken out and the whole mixture is replaced, and the roots are covered up. When new shoots spring up irrigation is given. Barnard (3) states that "Root pruning occasioned by winter ploughing to a depth of nine to ten centimeters is beneficial. The feeding roots are annual structures invariably associated with endophytic micorrhiza and are developed at a depth of five to ten inches at the base of the cultivation zone. The root growth commences about five weeks after the rise of sap begins, and three weeks after the burst of buds."

Root exposure

Grape vines require heavy manuring. Generally three to five baskets of (60 to 100 lb.) farmyard manure are given in the month of April, after pruning. Oil cake, sheep dung and all such available organic manures can be usefully applied. The use of sulphate of ammonia or niciphos to a limited extent is also recommended. No manure is usually applied to vines in the Deccan after the October pruning, as it is found to encourage vegetative growth and suppress fruiting if applied. It has been estimated that a five-ton crop per acre of fresh grapes removed 33 lbs. nitrogen, 9 lb. phosphate, 27 lb. potash, 71 lb. lime and 3·60 lb. magnesia. Potash deficiency causes chlorotic mottling which later lead to scorching and collapse. Boron deficiency

Manuring

in the berries becomes manifest by the appearance of brownish-green areas under the skin. Application of sulphate of potash and borax at the rate of 14-28 lb. per acre, cures the trouble in the course of two seasons (2). Farmyard manure is given at the rate of twelve to twenty tons per acre. Another fertilizer mixture recommended for grapes is :—

Sulphate of ammonia ..	150 lb.
Superphosphate (45%) ..	352 lb.
Muriate of potash ..	72 lb.
Sand	26 lb.

This mixture is applied at the rate of six pounds per vine preferably in two applications in the year. Some authors recommend green manuring in the absence of farmyard manure. In France prunings are returned to the soil which serve as a useful manure. The prunings may also be fed to livestock and enrich the soil in the form of cattle dung. Stene (74) has also found that some grape vine varieties respond very definitely to potash applications. Fertilizers poor in nitrogen and rich in potash and phosphorus should be applied especially when there exists a tendency to flower dropping. Lagatu and Maume (51) state that potash is necessary to vines, as failure to apply this in adequate amounts will cause leaf scorch, arrest of growth, yellowing of leaves and incomplete ripening of fruits. At New York, nitrogenous fertilizers have proved to be very effective in improving the yield, quality of fruit, leaf and wood growth of the vines (43). Lime had no appreciable effect on vines, while phosphoric acid and potash had so small a beneficial effect that their use was not profitable. Stable manure and green manure did not yield any consistent or conclusive results.

In Malta (14) vines are manured every third or fourth year. Shallow trenches are dug fifteen to twenty centimeters deep and farmyard manure at the rate of half to one basket per vine is put in them. It is reported that "excessive use of organic manures will produce grapes of inferior quality for the wine press."

The best manure for grapes, however, seems to be the stable manure which supplies organic matter or humus and is complete with most ingredients. Ten tons of stable manure applied

every third year may suffice to maintain the fertility of the soil. Stable manure is scarce and hence artificial manures, supplemented with green manure are applied. Vines over-supplied with nitrogen produce delicate shoots that are liable to fungus attack. While nitrogen promotes growth of cane and leaves, phosphoric acid gives tone to the vines and improves the quality of fruits. Either of the following manure treatments may be adopted with advantage in Bombay Presidency:—

(1)	Bone meal	1 cwt.
	Sulphate of potash ..	1 cwt.
	Sulphate of ammonia or nitrate of soda	1 cwt.
	or	
(2)	Bone meal	1 cwt.
	Blood manure	2 cwt.

These doses are meant for one acre. Vines may be manured in Bombay Presidency once in April and again in the winter, when bunches are formed. The manure should be applied in furrows six to eight inches deep on either side of vines and two feet away from them. The winter application would help the development of bunches and improve their quality, while manuring the vines at the time of April pruning is desirable to stimulate growth of the plant.

Irrigation

Grape vines require regular irrigation in the Deccan. Irrigation is given to them almost throughout the year, except for a few weeks at the time of April and October prunings, and during the monsoon, when water is applied only if there is a break in the rains. Without ascertaining that a sufficient supply of water will be available in the wells throughout the year, it is unwise to go in for vineyards. The summer months during which scarcity of water is felt in many parts of the Deccan is just the period when irrigation is required for this crop to foster the new growth after the April pruning. If the wells fail to give an ample supply of water at that time, the vines may be seriously damaged. Regular irrigation is also essential from October to March, which is the fruit bearing period. The method of irrigation common in these tracts is the flat bed or

round basin around each vine. But owing to the close planting and heavy irrigation applied, the system actually amounts to flooding. Flooding is unavoidable, because the soils are deep black and heavy, generally deficient in humus, and have a tendency to crack and dry up near the surface after each irrigation. Consequently, frequent irrigation and stirring the surface soil are necessary. Watering is given once in six to eight days during the fruting season. It may be noted here that the first watering after October pruning is sparing, just enough to wet the surface soil. The quantity is gradually increased to the full dose in the third or fourth turn. Heavy irrigation in the beginning encourages vegetative growth and is likely to suppress fruiting. De Castella (17) states that "The usual practice of giving a heavy irrigation when vines are in full bloom in summer, tends to produce excessive vegetative growth at the expense of the fruit." He suggests that under Australian conditions, after giving copious irrigation in August, the next irrigation can be given in November. Frequent irrigations are of course necessary during the summer, the first irrigation commencing when the buds are about to burst.

Thinning of bunches

In the Deccan, grape vines bear bunches chiefly after the October pruning. These bunches develop sweetness and quality, producing a marketable crop. After the April pruning also, the vines bear some bunches which, if allowed develop and mature during the monsoon. Such fruits become sour and unmarketable, since they do not seem to be able to synthesize sugar sufficient at that period of the year. It is, therefore, the practice to pick off all blossoms which appear after the April pruning, in order to conserve the energy of vines for the October crop. No thinning of bunches is practised in the Deccan in the case of the October crop. Knapp (50) while emphasizing the value of clean and careful cultivation in the vineyard, advocates keeping the bunches clean. In the case of loose or straggling clusters or set of shot berries or both, thinning of flower clusters is recommended by Winkler (83), who also recommends berry thinning, when they are too dense in the clusters, in order to improve quality.

It has already been mentioned that frequently grape vines get damaged by low temperatures in the Nasik area. It is

observed that when the temperature falls to 35° F, the foliage and tender parts of canes are altogether killed. Whenever low temperature is accompanied by strong wind, the damage is sudden and severe. Well-protected portions of vineyards, sometimes escape damage. Usually the lowest temperature is recorded between 3 a.m. and 8 a.m., when frost occurs. At present, no successful treatments to protect vines from frost or low temperatures have been discovered in the Deccan. Covering the vineyards is expensive. Burning of firewood in and around them and flooding are not efficient enough in the fight against frost. Observations show that burning wood and flooding do not raise the temperature of the field appreciably. It is noticed that there is a rise of only one or two degrees in fields where such methods are employed as compared with the temperature outside. Heating of orchards, as is done in California, has not been tried in this country on a large scale, due to the high cost of such methods. It may be possible to raise the temperature by five degrees Fahreinheit by using modern heaters. But this requires about one hundred heaters per acre and the cost of burning them for four or five hours may go to Rs. 150/- to Rs. 200/- per night.

Injury due to frost

When frost damages the crop, the temperature near the surface of soil is usually 24°F to 26°F, and the atmospheric temperature under shade is 31°F to 33°F. The Bombay Department of Agriculture has arranged to get timely intimation from the Meteorological Department when frost is expected in grape areas, and to send it to important centres by telegrams. But the benefits of such a service cannot be fully availed of by growers for want of proper means to fight against the adverse weather. In the year 1936, some preliminary experiments on the protection of grape vines from frost were conducted at Nasik. The observations included the effect of wind-breaks, oil heaters and fire wood burning. The tentative conclusions were that wind-breaks gave a temperature rise of two or three degrees Fahrenheit, modern oil heaters at the rate of two hundred per acre and country heaters gave a rise of six to seven degrees Fahrenheit only at a cost of Rs. 75 per night.

Cold waves are not known to do much harm to vineyards in Sind and North-West Frontier, as in those tracts the blossom appears in the months of February and March, when there is little

likelihood of the occurrence of low temperature. Further, the existence of severe winter conditions during December and January force the vines to dormancy.

Improvement of grapes by raising seedlings

Effort has been made to improve the quality of *Bhokari*, which is the most important commercial variety of grapes in the Deccan, by raising seedlings of this variety and making selections from them. Out of a large number of seedling vines raised and reared to fruiting, some produced fruits of better quality than *Bhokari*. But it has to be seen yet whether these selected seedlings are also high yielders. Seedling No. 94 appears to be promising. The main features of this seedling are:—

> Vine growth fairly vigorous, stem brown, cylindrical, glabrous, young growth smooth, internodes short, tendrils more frequent, occurring practically at every node; leaves membranous, basal lobe overlapping only in the advanced stages; clusters occur opposite the fifth leaf, the bunch is long and compact, berries oblong and fairly well-developed; colour yellowish tinged with green; pulp soft and melting; taste mild acid. It is good for table purposes.

It appears possible to develop strains or varieties, which are late or early, and which are resistant to diseases by pursuing breeding work further. Grape selections that have recently been made in certain countries for the resistance to the attack of certain diseases show that, certain strains are satisfactory. Observation on resistance to cryptogamic diseases made in one country may not, however, be applicable to another. Fennel (35) describes his search for suitable species in south of Florida and his hybridization experiments. Some 100,000 seeds were sown, and thousands of seedlings have already been planted out. The new varieties which would be evolved may be more adaptable to tropical conditions than those raised from species of temperate regions.

Dearing (30) reports that the native vines and muscadine grapes, have been greatly improved by crossing and selection. One of the most striking results has been the creation of self-pollinating kinds with complete hermaphrodite flowers.

Improvement of grape vines by bud selection has been

attempted and several types are reported to have been selected as bud sports and propagated true to type.

Sterility in grapes

Sterility is marked in grapes and due to this phenomenon, there are a number of grapes which are seedless. The *Pandhari Sahebi* is practically self-sterile and shy bearing. When grown side by side with *Bhokari* it bears better crop and produces uniform berries due to fertilization with the pollens of *Bhokari* (31). Roussopoulos (69) mentions that optimum climatic conditions combined with heavy manuring encourages the development of seeds in seedless types. Stout (75) reports that "Varieties like the Bright Lindley, Baty and Massasoit, have curved instead of erect stamens, and the stamens are more or less aborted and have shrivelled and defective pollen grains. Self-fertilisation in these types is rare, and intervention of foreign pollen is necessary." He adds that "There is a group of grape varieties which produce pipless or almost pipless grapes. . ."

Food value

As in other fruits, varieties of grapes differ in their food value. As a rule grapes are stated to be a fair source of calcium, phosphorous and iron. Some varieties like Concord and Isabella, were found to be poor sources of vitamins A and B, while C and G vitamins were entirely absent in them when tested without skin. Sultanina and Malaga grapes with skin on the other hand showed small quantities of vitamin A, fair amounts of vitamin B, little or none of vitamin G, and very little of vitamin C. Commercial grape juice is reported to have no vitamins at all. (Also see pages 342 and 343.)

According to Winton and Winton (85), grapes (American) contain 22·60% total solids, 1·3% protein and 0·5% total ash.

Sherman (72), on analysis found the composition of American and European grapes as follows:—

Edible Portion	American grapes.	European grapes.
Water	81·9%	81·6%
Protein (N×6·25)	1·4%	0·8%
Fat	1·4%	0·4%
Carbohydrate including fibre	14·9%	16·7%
Ash	0·45%	0·46%
Fuel value per 100 gms.	78 cal.	74 cal.
Fuel value per lb.	355 cal.	355 cal.

Quantitative data of Vitamin content of grapes are reported to be as follows by Daniel and Munsell (27).

	Vit. A	Vit. B	Vit. C	Vit. D	Vit. G
Grape (*Vitis* spp).					
Concord	66	—	—	—	—
Malaya	21	11-13	6	—	0
Thompson Seedless (Sultana) ..	50 (Int)	33	3	—	—
Tokay	50	—	—	—	—
Frozen (Thompson Seedless) ..	25 (Int)	12	Gradual loss	—	—
Raisin (Thompson Seedless) soda dipped, sulphured, dehydrated	178 (Int)	0	0	0	50

Int. means International Units and others denote Sherman Units.

Work done in India shows the following analysis of grapes:

Name of food	Botanical name	Moisture %	Protein %	Fat (Ether Extraction) %	Mineral Matter %	Fibre %	Carbohydrate %	Calcium (Ca) %	Phosphorous (P) %	Iron (Fe)mgs %	Calorific Value per 100 gms.	Carotene (Int. Vitamin A unit per 100 gms.)	Vitamin B (Int. per 100 gms.)	Vitamin C (mgs. per 100 gms.)	Calories per ounce.
Grapes (Blue variety).	*Vitis vinifera.*	85·5	0·8	0·1	0·4	3·0	10·2	0·03	0·02	0·4	45	15	Trace	3	13

A great deal of damage is done to the vineyard in the Deccan both by the powdery and downy mildews.

Powdery mildew is caused by *Uncinula necator* and the downy mildew by *Plasmopara viticola*. The first signs of downy mildew are seen on the leaves as greenish yellow, more or less circular spots known as "oil spots", which appear more transparent than the normal tissue, when the leaves are held against light. In moist warm weather, the glistening downy mildew makes its appearance on the under surface of leaves and can be easily scraped off. The affected spots ultimately turn brown, dry up and crack. Downy mildew also attacks young bunches causing them to dry and fall off. Affected shoots are dwarfed and they may die. The fungus, however, cannot attack ripe wood of vines. Affected berries become hard and finally shrivel into mummies. Powdery mildew appears first as whitish patches, later turning greyish white on both the surfaces of leaves. The spots do not turn brown as in the other case. The mottled appearance of the leaves attacked by powdery mildew is different from the more or less well demarcated spots of downy mildew on the leaves. When the blossom is affected with powdery mildew it fails to set fruits. When young berries are affected, they do not ripen. If attacked when half grown, the fruits crack and are disfigured by spots. The cane is also affected. The following is the programme of treatment of the two mildews:—

Diseases and pests

1. Prune vines in the first fortnight of October, as those pruned early in September are open to the serious attack by downy mildew, whilst those pruned late in October or early November do not sprout well.
2. Apply Bordeaux mixture (3: 3: 50) when shoots are three or four inches long, followed by another application after a fortnight or so. If the weather continues dry after the second application, there will be no need for the third application. However, if late heavy rains are received in November a third application of Bordeaux mixture will be beneficial, but it must be made before flowering, as it causes damage to young flowers.
3. During flowering, apply sulphur dust at the rate of ten

SPRAYING BORDEAUX MIXTURE ON GRAPE VINES WITH A BUCKET SPRAYER.

Facing page 345.

to twelve pounds per acre. Sulphur dusting at the time of flowering is extremely beneficial as it helps setting of berries.

4. The second application of sulphur dust should be made about a month after the first dusting, and the quantity of dust used at this time should not exceed ten pounds.
5. The hot weather (April) pruning should be done about the first of April, so that the vines can have their canes properly matured, before monsoon sets in in June. It is desirable to spray vines early in June with Bordeaux mixture (5: 5: 50). Failure to spray vines before the rains, may result in the shedding of leaves in September, and the early sprouting of buds due to mildew attack.

If this programme of treatment is carefully followed, the vines can be kept almost free from mildews. Bordeaux mixture is perhaps the most common fungicide in use. It is used in different strengths as may be needed by the seriousness of attack, and the nature of the causal organism. For a normal solution, five pounds of copper sulphate, five pounds of quick lime and fifty gallons of water are taken. The copper sulphate is dissolved in four gallons of hot water in a wooden tub or an earthenware vessel. No metal vessel should be used for copper sulphate solution, as the chemical acts on the metal. To the above solution cold water is added to make it up to ten gallons and stirred. In another vessel, five pounds of best quick lime is slaked and then enough water is added to it to make up to ten gallons. The copper sulphate solution is then poured slowly into the lime suspension, constantly stirring the mixture. Bordeaux mixture is then ready for spraying, on the addition of the remaining amount of water to make up the whole to fifty gallons. Bordeaux mixture should be properly prepared so as to have no free copper sulphate in it. This is tested by immersing a clean blade of a steel knife in it. If a reddish deposit is seen on the blade, then more lime water should be added to the mixture, and stirred, until the knife blade remains clean on dipping.

Bordeaux mixture

Anthracnose is caused by the fungus *Gloeosporium ampelophagum* which produces cankers or scars on leaves and

shoots. The scars appear at first as small brown spots, which enlarge and become depressed in the centre. Affected blossoms appear as if charred.

Anthracnose

The well-known "bird's eye spots" are produced by depressions on berries. The central portion of the spots is grey and somewhat depressed and is surrounded by a circular red-purple zone. Moisture in the form of rain or dew drops is necessary for the germination of anthracnose spores and infection for the vines. Low temperatures favour the development of anthracnose which is a slow spreading disease, and does not devastate the crop with such rapidity as downy mildew does.

The disease can be controlled by spraying with Bordeaux mixture (5: 5: 50). On pruning, all the branches are cleaned and the stem is sprayed with Bordeaux mixture. In severe cases Bordeaux paste which is but a concentrated preparation of Bordeaux mixture, being in the proportion of 1·5 lb.: 1·5 lb.: 10 lb. is smeared on vine stems, after pruning.

The only severe insect pest of vines in the Deccan is *Scelodonta strigicollis* M. which is locally known as *Udadya.* It eats up the tender growth of spurs. The colour of this beetle is dark brown black with bright bronzy reflection. The beetles feed on growing shoots and leaves and damage the vines considerably. The larval and pupal stages are passed in the soil. Mechanical control is very effective by (1) removing bark of the vines to avoid egg laying ; (2) trapping the adults in six to nine inches in length, *Tassels* formed of banana leaves placed on the pruned ends of vines near the sprouting buds, where the insects take shelter in these bundles and are shaken of at intervals in a vessel containing kerosene and water; (3) the most effective way is the "Umbrella" method of passing an inverted umbrella under the vines and collecting the beetles in that by shaking the vines. The beetles are then collected in gunny bags painted inside with coal tar. The use of Bordeaux mixture and calcium arsenate is recommended in Madras.

Insect pests

There is another type of beetle (*Adoretus ovalis*) seen attacking grape vines at Nasik. This pest appears in November. Hand-picking of these insects is recommended. Dead wood on vines in which they hide should be removed and burnt to remove all shelter to these pests. The

Cockchafers

common practice in the grape-growing districts of the Deccan is to peel off all dead and dry bark of vines, thus cleaning them soon after pruning is done. In vineyards which are not cleaned in this way from time to time and in which the vines possess many unclean knots, the pests do great harm to the crop.

Thrips

Rhipiphorothrips Cruentatus H. are minor pests but in case of severe infestation the shoots may wither away. Spraying with Nicotin Sulphate or tobacco decoction is quite effective.

Harvesting

Different varieties of grapes develop different hues on their bunches, when the berries are ripe. The *Bhokari* develops a pinkish colour on the berries when they are fully ripe. The bunches are usually ready for picking when the peduncle gets somewhat shrivelled, and the characteristic hue is fully developed. In the Deccan, grape bunches are harvested by hand. Picking is done a few days earlier when bunches are meant for distant markets. There is no systematic observation made on the right stage of ripening of grapes in this tract. But it is best to harvest grapes, when they are fully ripe on the vines. In America, the harvested bunches are allowed to wilt in the packing house until the stems are perfectly dry. Bagging of bunches with thin manilla sacks is also done as a protection against insect attacks. The bags are usually provided with two or three small holes in the bottom to drain out the water that may enter them. Bioletti (9) states that berries of young vines ripen quicker than those of old vines. He also states that berries exposed to the south ripen earlier than those to the north. Bunches at the base of the stem ripen earlier than those at the top.

Marketing of grapes

The method of packing, marketing and transporting of this delicate fruit in India requires a good deal of improvement. At present the fruit is packed in ten-pound bamboo baskets, with grape leaves or dry grass as packing or padding material. Grapes from Ahmednagar and parts of Southern India are packed in earthen pots, holding about twenty to twenty-five pounds each, with or without saw dust for packing. The earthen pots locally called *madkis*, are carefully handled in transit by the railwaymen for fear of breakage, and hence the fruits inside them are not damaged much. The baskets from Nasik

are principally sent to the Bombay market by railway, and sold by the commission agents at the current market rates. The commission agents charge either one anna per rupee or four annas per package as their agency commission. No special care is taken to pick bunches at the proper stage of maturity. This lowers their value in the market. Besides, some of the bunches are damaged in transit also. Such conditions coupled with irregular methods of sale in the market work adversely on the economics of grape cultivation. The Baluchistan (Chaman) grapes are brought to the markets of Bombay in willow baskets of forty pounds capacity packed in grass and carried in refrigerated vans. The fruit is sold in the market by auction sale and not by the "secret treaty" method common in the case of other fruits. For long distance markets like Calcutta and Madras, grapes are packed in wooden boxes. Grapes of good quality come to the Bombay market from Italy and Spain also. They are packed with cork dust in wooden barrels. The fruit is shipped under refrigerated conditions. These grapes fetch a good price.

In France, the picking of grapes is standardised, the standards differing for different varieties. Trays of varying dimensions are used for packing grapes.

Storage

The methods of grape storing by packing the fruit among layers of cork is only applicable to certain varieties. Some grape varieties can be easily preserved as they are grown in extremely dry climate which increases the percentage of sugar in the berries. Some types of grapes keep for a long time, if cut and placed in layers on saw dust in receptacles, but will not keep well if left hanging on vines. White saw dust, a mixture of fir and spruce, showed much better results as a packing material for grapes than red-wood saw dust or cork at 32°F. The optimum range of storage temperature for grapes of several varieties is said to be 28°F to 32°F (80). The storage life may vary from two to six months according to varietal and environmental factors under the best storage conditions. According to Reyneke and Du Plessis (68), S. African grapes are very susceptible to damage from sulphur dioxide fumigation, but in certain trials, when fumigated with 0·25% to 0·3% SO_2, they have survived in exceptionally good condition. High temperatures

during SO_2 fumigation also materially increase damage. Spraying the packing material at the bottom of the grapes with 20 cc. of a solution containing 20 g. potassium or sodium bisulphite in 100 cc. water per 10 lb. box (*i.e.*, 1 tablespoonful per box) resulted in the grapes maintaining their freshness and attractiveness in comparison with untreated boxes in which much of the fruit rotted. They further add that the S. African consumer prefers a well-coloured grape with a high sugar content and if possible, unusual flavour.

For inland distribution the most suitable transport temperature is 60 degrees F and facilities to maintain this temperature on rail are very desirable and should cost less than the cooling of insulated cars to 40 degrees F by means of ice as is now done (34).

Economics of grape cultivation

It is calculated that the total receipts per acre from grape vines might go to Rs. 1,500 or more.* But it costs about Rs. 1,000 per acre to maintain the vineyard and to cultivate it well. The net profit per acre is, therefore, about Rs. 500. This is of course exceptional and these figures are rarely reached under normal conditions. The net profit of Rs. 500 appears to be an attractive figure. But if, once in three or four years as it happens in the Deccan at present, the crop is damaged by frost, the whole profit is wiped out. Hence, of late, grape cultivation has become a fairly risky undertaking in the Nasik district. However, heaters and other precautionary measures against frost are being commonly adopted. In the Madura District of Madras Presidency, an amazingly high yield of about 25000 lbs of the local green grape is claimed by some growers, while Kishmish, the seedless variety of Baluchistan is reported to yield about 15000 lbs. per acre per year.

Drying of grapes

The conditions for drying grapes are not very suitable in the Deccan. The percentage of sugar in the Deccan grapes is very low. Besides, incidental showers in the month of April cause a good deal of damage to the fruit in the process of drying. Some enterprising growers, however, have dried their *Bhokari* grapes for trial.

*The figures prevailed in the' thirties. During and after World War II, the cost and income figures have risen even three to four times.

Although the product obtained was not of a superior quality, grape drying appears to develop into a useful side industry when fresh fruits do not fetch a good price in the market. Other varieties were not tried for their drying quality. Moreover, their production is low, and there is usually little fruit available for drying. Well washed grapes are dipped in lukewarm lye solution for just a minute or two and then thoroughly rinsed in cold running water. They are then exposed to sulphur fumes in a sulphur box for one hour and then either dried on wooden trays in the sun under dust-proof conditions as far as possible or dehydrated in the home-drier at a temperature of 160°F. The dried raisins are then graded and packed in air-tight paper-lined wooden cases.

In 1913, most of the world's raisin production was reported to be restricted to California, Turkey, Spain and Australia. Muscats, Sultanas and Currants are the three most important varieties used for raisin manufacture. The seedless raisins are made mainly from Sultana, Sultanina, Black Corinth and White Corinth. The method of preparing raisins is described by Cruess, Christie and Flossfedef (24). The fruits are dipped first in a boiling solution of half to one per cent lye (sodium hydroxide) for three to five seconds. Some varieties like Muscat and Malaga require two to three per cent lye solution for satisfactory results, and the time of dipping may last upto fifty seconds. Dipping in lye imparts a glossy appearance, facilitates evaporation and renders the raisins sweeter. Special dips containing olive oil, glycerine or mineral oils appear to improve the colour and keeping quality of raisins. The dipped grapes are rinsed in fresh water and then dried in sun or in evaporators. Twenty to thirty-three days are required for drying undipped grapes while dipping reduces the time by about one-third to half. Some grapes are fumigated with sulphur fumes before drying. Sultanina requires fumigation for half an hour, while red wine grapes that are to be sun-dried require to be exposed to sulphur fumes for one hour. Solid bottom trays are preferred for drying operation. The evaporated grapes have to be kept in sweat boxes or bins for one or two weeks to permit equalisation of moisture in the raisins. It is said that grapes dried to twenty-four per cent or twenty-five per cent moisture will keep well under California conditions.

Some varieties have to be subjected to the process of seeding (removal of seeds) after drying.

Late picked grapes may sometimes be dried in chambers at a temperature of 160° F. In California, it was observed, that the drying ratio is regulated by the sugar content. To obtain raisins of first quality, Muscat grapes should not be picked when their juice reads below 25 degrees Balling, nor Sultanas below 23 degrees (Balling indicating sugar content). Raisins are prepared on a large scale in California. Currant grapes are dried on a large scale in Greece. Sultana is dried in Asia Minor. Monuka is a special dried grape of Afghanistan. In Baluchistan and North-West Frontier, grapes are dried entirely in the sun. But some preliminary trials conducted in this country several years ago, showed that good raisins can be prepared by adopting the American method of evaporation using a small dehydrator of the type described elsewhere for drying figs and banana.

Ciferri (23) states that in the province of Macerata in Italy, it is the custom to keep fresh grapes for domestic consumption. The bunches of ripe grapes are hung up in a cool place preferably in a well-ventilated cellar. Thus stored, grapes keep for a long time, though they shrivel and assume a colour varying from amber to brownish yellow, having in short the characters of dried grapes. Dried grapes are liable to the attack of *Macrophoma flaccida* along with mildew.

Unfermented grape juice has been used as a popular beverage for centuries in many parts of the world. For bottling fresh grape juice, it is very necessary that the fruit should be juicy and aromatic, so that the juice can have its "character." Taking this into consideration, Black Prince is perhaps the only type in the Deccan, the juice of which can be satisfactorily bottled. Grape juice is being canned in the United States of America on a fairly large scale. Bottling grape juice is not a very elaborate process. The fruit is pressed, and the juice on being collected is mixed with "German soil" and heated to 65°C and filtered. This filtered juice is then bottled, and pasteurised at simmering temperature (80°C) for twenty to thirty minutes, closed air-tight while still hot and stored. In the case of coloured grapes, a little juice is added to the pomace, which is treated to a temperature of 160-165° F in order to extract the colour. It is then pressed

Bottling of grape juice

and the extract filtered and mixed with the bulk of the juice to be bottled. Bottled juice of most varieties of grapes leaves a thick sediment of tartrates, when stored for some time. In such cases, it is necessary to open the bottles after a few months of storage, syphon off the clear liquid, bottle it again and pasteurize as described above. There does not seem to be much demand for fresh or bottled grape juice in the Indian market, where sufficient taste is not yet created to develop bottling of grape juice into an industry. But a limited sale of juice is possible if it is properly bottled and packed. Grapes furnish a large variety of products such as wines and syrups (15). Jelly and conserves can also be prepared from them, while in France and along the Mediterranean coast choice wines are manufactured out of grapes. The manufacture of syrups is easy and can be followed on the lines of fig or any other fruit syrup.

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CHAPTER VIII

SAPOTA OR *CHIKU* (*Achras sapota* L.)

Sapota is a popular fruit in most parts of India, though not of very great commercial importance except in a few regions. It is known by a number of names in different parts of the world, such as *chiku* (or *chico*) in Bombay Presidency, bully tree, *ratami* and *shimai-eluppai* in Ceylon and extreme South of India, naseberry in West Indies and sapodilla or sapote in several other parts of the world. Its scientific name, *Achras sapota* is sometimes confused with *Achras zapota* L. The latter is popularly known in America as sapote or mammey sapote, both of which terms closely resemble the common name of sapota applied to the former. Both the fruits belong to the family *Sapotaceae* and are classified under the group of tropical fruits.

Introduction

In India, the *chiku* is the only kind that is of any importance. It is grown in this country solely for its fruits. The following distinguishing characters of other similar fruits are given in order to avoid the possible confusion that may arise owing to the close resemblance of the popular names. The sapote or mammey sapote is an erect growing tree with large leaves resembling in outline that of loquat (*Eriobotrya japonica*). While the leaves of sapota are smaller, leathery, very thick and dark green or shining green in colour, those of the mammey sapote are shining light green above, and light brown beneath. The fruits of the latter are ovate to elliptic in form, while those of the former are round oval, ovate or peach or apple-shaped. Sapota fruit has a thick scarfy skin with nut-brown colour and a yellow-brown and soft granular flesh, while the mammey sapote has a thick and woody rind enclosing a firm pulp of a reddish colour. Sapote has a single seed in each fruit, and this is ordinarily elliptical in shape and brown in colour, hard, smooth and shiny, but the fruits of *chiku* have several shining black smooth seeds. The flower of the sapote is borne severally in the axils of fallen leaves on the older wood.

There is still another fruit, which bears a similarity in name to the *chiku.* This fruit is designated in California as white sapote (*Casimiroa edulis*) and is grown extensively in Mexico and to a small extent in southern California. It belongs to the family *Rutaceae* to which the citrus fruits belong. The fruit of white sapote resembles a quince in shape and has a soft and very sweet pulp, tinged with a slight bitterness. The skin of the fruit is smooth, green to yellowish green in colour, sometimes with a dash of bright orange or yellow. The leaves are palmate, and dark green in colour. Unlike the white sapote and the sapote, the *chiku* is grown both for fruit as well as for the manufacture of chewing gum in America. It yields a white latex from which chicle used in the manufacture of chewing gum is obtained. The green sapote (*Lucuma viride*) and the yellow sapote (*lucuma salicifolia*) are other plants which are likely to be confused with that of *chiku.* The green sapote tree resembles the sapote in general appearance and habit, while the yellow sapote is a small tree bearing a slender orange yellow fruit. Neither of the two varieties are grown in Indian orchards.

Origin and distribution

The original homeof *chiku* trees is the Tropical regions of South America. Its cultivation is extensive in Mexico and neighbouring countries. It has now spread to other Tropical countries, including Central America, South of Florida, Ceylon, Jamaica and Philippines, where it has merited some attention. In India the cultivation of *chiku* is concentrated in the plains of the United Provinces, Bihar, Madras Presidency and Bengal and on the Western coast of the Bombay Presidency, especially in the districts of Surat, Thana and Kolaba. Some large old *chiku* trees are said to be growing in parts of Jamnagar, Junagadh and Gondal states in Kathiawar. Of late, it is slowly spreading to other parts of Western India like Poona, Nasik, Ahmednagar and Bijapur districts. In South India, the Vizagapatam district is the leading chiku growing centre. The district of Navsari in the Baroda State has a good deal of *chiku* cultivation which is extending further. The tract lying between Bombay and Surat in particular seems to offer the most suitable conditions of soil and climate for the growth of *chiku* trees, so much so that the cultivators of this tract have specialised in its cultiva-

tion. In the Bombay market, the *chiku* fruits of this tract are renowned and they command a high price due to their superior quality. These trees were first introduced into this tract in about the year 1898 at Gholwad, a small village about seventy miles to the north of Bombay. *Chiku* was then grown in the vicinity of Bombay, as a rare and costly fruit plant. It has since then very speedily spread to Dahanu, Gholwad, Umbergaon and the neighbouring places. The total cultivation of *chiku* now extends over an area of 2,000 acres in this tract. It is fast increasing because of the hardy nature of the trees, profuse bearing, freedom from any serious pests and diseases and availability of fruits almost throughout the year.

Varieties

The varieties of *chiku* remain yet to be properly studied and classified. Commonly, two chief types of fruits are recognised in the Bombay market one has round fruits and the other oval ones. But fruits of both shapes are found on the same trees at the same time or in different seasons of the year. Seasonal changes are said to influence the shape of fruits considerably. There is, however, a great variation in the branching habit, foliage and bearing of trees, as well as in the texture of the skin and colour and shape of fruits. A few of these characters seem to be correlated. The trees mostly present a great predominance of certain characters in preference to others. On this basis, an attempt is made here to group sapota trees as follows:—

(1) Tree habit erect; branching in whorls; foliage deep green; leaves broad oval; fruits large with smooth yellowish skin; pulp sweet and butterlike.

(2) Tree habit drooping; branching in whorl; the foliage light green; leaves narrow elliptical; fruits small with rough brownish skin; pulp inferior in taste.

(3) Tree habit spreading; branching irregular; foliage deep green; leaves broad oval; fruits with smooth yellowish skin; pulp sweet and butterlike.

(4) Tree habit spreading; branching irregular; foliage light green; leaves narrow elliptical; fruits small with rough skin; pulp inferior.

Each of these groups may further be subdivided into two sections depending upon the shape of fruits, which may either be chiefly round or oval.

Some trees have fruits with pointed ends, and resemble the playing top. Others have predominantly egg-shaped fruits. Generally, large fruits seem to be associated with broad oval leaves. Small and inferior fruits go with narrow long leaves. In the Surat and Navsari districts, the following distinctive varieties are recognised, of which the first three alone are extensively grown:—

(1) *Kali.* Leaves broad, thick and green in colour; fruits borne in singles; fruit quality high; main picking season winter; fifty per cent gooties of this variety strike roots.

(2) *Dhola diwani.* Leaves light in colour; fruits whitish and oval in shape; fruits superior in quality to Kali; main picking season early summer months; gooties strike roots easily on the tree.

(3) *Large Calcutta.* Leaves light in colour; fruits fifty per cent larger than those of other varieties; gooties difficult to strike roots; grafted on *rayan* (*Mimusops hexandra*).

(4) *Long.* Leaves narrow and small, looking longish in shape; gooties strike roots very easily; fruit thin and long and very sweet in taste; bearing very poor and hence not commercially paying.

(5) *Bhuri.* Foliage thick; leaves medium sized; bearing medium; fruits large and of high quality; tree shapely.

(6) *Jingar.* Tree medium; leaves small; fruits very small, fruits borne in bunches; gooties strike roots easily.

(7) *Vanjet.* This is a sterile or male type. Tree grows slowly and produces knots on the branches; often roots emerge from these knots; bearing very shy; fruits are good to eat; gooties strike roots easily.

Round about Vizianagram in the Madras Presidency sapota cultivation has received a good deal of attention in recent years. Over a dozen varieties are recognised there, the most important of which are listed below:—

(1) *Kittubarti.* Very small egg-shaped fruit, with four to six ridges on the rind; skin is rough, medium thick and has a buff colour; taste very sweet when fully ripe. There is also a variety called Kittubarti big,

which bears big hard fruits suitable for long transport, but inferior in quality to small-fruited varieties.

(2) *Bangalore.* Large sized oval fruits, with about nine ridges running from the base to the apex; apex round as compared with the slightly tapering form of *Kittubarti*, flesh gold coloured with musk melon tinge towards the core; medium sweet.

(3) *Jonnavalosa I.* Medium sized fruit, similar in shape to 2, but less broad at the sides; skin rough, thin, with no ridges; cream coloured flesh near the skin; but assumes a pinkish tinge towards the core; sweet.

(4) *Jonnavalosa II.* Medium sized fruit, ovate, has a prominent depression near the stalk end, skin buff coloured, with whitish flakes and eight marked ridges; flesh musk melon coloured with golden tinge near the cavity. Sweet, but has a rather unpleasant flavour.

(5) *Pot Sapota.* Small sized fruit, oval with a pointed apex, ridges absent, thin skin and walnut coloured flesh, very sweet with agreeable flavour; bears fruits even when grown in pots; hence the name.

(6) *Gauranga.* Small sized fruit, ovate, with, one shoulder drooping and the other raised. Eight to ten marked ridges; flesh soft, melting and very sweet.

(7) *Thagarampudi.* Medium sized fruit, round to oval with a flat base; skin rough but thin; no ridges; flesh buff coloured, melting, juicy and streaked, very sweet. Even when picked green, fruits ripen well, unlike in other varieties. Good for export.

(8) *Ayyangar.* Large sized fruit, round to obovate with a slight cavity at the stalk end; ridges not prominent; skin very thick and buff coloured; flesh has pinkish tinge towards the core, rose scented, sweet and with pleasant flavour.

(9) *Bombay.* This variety bears both round and oval fruits of different sizes and is perhaps identical to those grown in Bombay, Bihar and Bengal.

(10) *Dwarapudi.* Largest sized fruit, round, sweet and much in demand.

(11) *Cricket Ball Sapota.* This is grown at Coimbatore and

on the lower foot of the Nilgiris. Fruits of very large size, round, very sweet, but not of any distinctive flavour.

(12) *Jonnavalosa Round.* Large sized fruits, shape nearly round, but sometimes obovate, and oval fruits are also met with; small cavity present at the stalk end; ten to eleven ridges; cream coloured and firm flesh; very sweet.

The above nomenclature is not accepted as standard although the distinctive characters of the different varieties are recognised. On the West coast of South India, all the varieties are classed into three groups, namely, the round, the oval and the large sized. In the United Provinces a variety known as the Plum Sapota is grown around Saharanpur. Most of the characters mentioned above as distinctive of the various varieties are more or less superficial and highly variable. As in the case of several other Indian fruits, so in *chiku* the proper study and classification is an urgent need to regulate its economic extension. A great headway has yet to be made in standardising these varietal names. The existing grouping is often confusing and indefinite.

Soil

Chiku trees are seen growing on a variety of soils, including the most porous sandy soil of Gholwad and the medium black soil of Kopergaon (Rahata). But a well-drained deep and porous soil, like that of Gholwad, Dahanu and Gandevi (Baroda State), is specially suited to their proper growth. A layer of hard murum at a depth of two to three feet from the surface is harmful to the luxuriant growth of the trees as well as to their profuse bearing. In such soils the trees grow well for a period of about eight years, and when the roots strike the murum layer below, the growth of the trees is arrested, the foliage turns pale, and the bearing as well as the size of fruits diminish. Examples of this phenomenon are seen at Gholwad and other places. In soils which form a hard cake at the surface after the rains, the branches of *chiku* trees wither, ultimately leading to the death of the trees. In very loose soils, strong winds during the monsoon shake the trees violently, with the result that the roots are torn and considerable damage is done to the trees in this way. In Ceylon (12) the sapota is said to prefer a rich sandy loam, although it has been known there to do well even in poor soils if well manured. In South India

sapotas have been grown successfully on gravely poor laterite soils of the hill slopes of the Western Ghats. The Indo Gangetic alluvial soil of Bihar and the United Provinces are very well suited for its culture, provided the climate is not too cold during the winter.

Climate

The climate of the tract between Bombay and Surat is equitable. The maximum and minimum temperatures approximate 92°F and 52°F respectively. The average rainfall is about sixty inches per annum, and is distributed over three months from June to the end of September, the heaviest rainfall being during the months of July and August. The tract is coastal and winds are very strong at the break of the monsoon. The humidity of the atmosphere is generally high. The sapota plantations here are exposed to the direct salt breeze from the sea and have to be protected by suitable wind-breaks. *Bhend* (*Thespesia populnea*) trees are planted all round the sapota plantations for this purpose. Cocoanut trees are also raised in thick rows, to provide a wind-break as well as for augmenting the income to the owner If this wind-break is not provided the foilage of *chika* trees on the seaside is scorched severely, and this causes considerable damage to the trees. This phenomenon is noticeable in many orchards at Gholwad (3). Parsons (12) thinks that, in Ceylon the sapota "is best suited to the low country wet zone, but will thrive in less moist regions also." *Chiku* is very susceptible to cold injury even when it has grown to be a large tree, and very rarely thrives where frosts are frequently experienced. This is the reason why it is scarce in the Punjab and the lower foot hills of the Himalayas. In the southern parts of the United Provinces and Bihar, however, sapotas are in greater evidence and thrive especially and well in sheltered localities.

Propagation

All over the world, sapota is propagated by seed, gooty and enarching. Parsons (12) states that budding is also possible. If seeds are used, they are selected from outstanding trees of merit, and sown in pans or prepared beds of light sandy soil in Ceylon. Seedlings are transplanted usually when they are about two and half months of age, and are finally planted out twelve to fifteen months after sowing. In South Florida, the propagation is mainly by seed, although it is said that shield budding, grafting and layering are feasible.

May is believed to be the most satisfactory month for budding in that country. Seedling trees produce fruits which are markedly variable, and therefore, vegetative methods of propagation are now being advocated. The most common method of propagating *chiku* trees in Western India is by gooty (Marcottage). Of late, grafting is displacing gooty at Dahanu and roundabout, because this method is easier, and the plants so propagated grow quicker (3). When the *rayan* (*Mimusops hexandra*) rootstock is used, the bearing is said to be good too.

Gooty

Chiku gooties are generally prepared at the end of May or the beginning of June, so as to give them the full benefit of the following rainy season.

From October the gooties are hand watered till the following January, when roots are seen to emerge. They are then severed from the parent tree, and planted in earthen pots and kept in shade until required for sale or planting. Nearly half the number of gooties die subsequent to severing in the pots. Gooties of *chiku* plants thus take eight months to be ready, unlike other plants which get ready in a much shorter period. The long time taken and the small success are the factors which raise the cost of gooty plants. An improvement in the method of preparing *chiku* gooties is lately coming into vogue. After the gooties have passed the first rainy season while still attached to the scion, they are left as they are, without any watering, until the *next rains*. In the second season, they throw out more roots in August. This method saves the cost of hand-watering from October to January and also makes the season of severance more favourable. A rainy day is considered very favourable for severing *chiku* gooties from their parent trees. The above practice is prevalent in parts of South Kanara district of the Madras Presidency where the rainfall exceeds 100 inches per annum.

Layering

Layering is found to be an easier operation than gooty in the case of branches growing close to the ground. Such branches require to be pruned to enable proper cultivation of the orchard land. They are, therefore, used for preparing new plants by layering. Layers, however, take a fairly long time to strike root, and, therefore, do not get ready for planting out for several months.

A special method of layering of litchees, but sometimes of

chiku also, is prevalent in and around Dehra Dun in the United Provinces. Earthen pots with a V or U shaped notches at two places opposite to each other and on the edges, are tied to the limbs of the trees close to the shoots intended to be propagated. After the usual operations of exposing the bark of selected shoots are carried out, the shoots are bent and passed through these notches and the exposed parts of the shoots are buried under the soil inside these pots. The separation of the layered plant is effected after a very long period.

Rootstocks

Some of the varieties of *chiku* are very reluctant to strike roots by the gooty and layering methods. They have, therefore, necessarily to be propagated by grafting, which method is lately becoming popular for most varieties. *Chiku* seedlings take a very long time to be ready as rootstocks, and hence the *rayan* (*Mimusops hexandra*) and *mohoda* (*Bassia latifolia*) stocks are preferred. Opinion, however, widely differs on the comparative vegetative growth and bearing of trees raised on each of these rootstocks. In Ceylon the two trees *Bassia longifolia* and *Sideroxylon dulicificum* the "Miracular fruit" of tropical West Africa, are said to afford suitable stocks for grafting sapotas (12). *Mimusops kauki* is said to be used as rootstock for sapotas in Hyderabad (Deccan). Sapota trees on *khirni*, however, are reported to be not prolific. At Saharanpur, it is said, that sapotas have been successfully enarched and cleft grafted on *Mimusops kauki*.

Side grafting of sapota on Mimusops hexandra has been done successfully at Kodur too, and a few sapota trees grafted on this and also on *Bassia latifolia* and *Bassia longifolia* are now growing there in an observational row.

Grafting

Self-sown seedlings of *rayan* and *mohoda* or *mohwa* are obtained from the jungle and planted in pots for rootstock purposes in the Bombay Presidency. When they take root in pots, they are grafted upon. Grafted trees are popularly believed to bear fruits with granular pulp, which is not relished in Bombay. Gooty trees have, on the other hand, no such disadvantages and, therefore, have been preferred by the Bombay public for a long time past.

In the neighbourhood of Gholwad, the land is levelled and pits are taken twenty to forty feet apart in the summer. Pits are usually dug three feet each way. They are filled with

brushwood or rice husk and burnt. They are left exposed for weathering until the approach of monsoon, when they are filled with a mixture of about eighty pounds of sheep dung or farmyard manure, and the original soil. About thirty pounds of whole or broken bones are often thrown at the bottom of each pit before filling.

Planting

Planting is done either in the beginning of May, in which case the plants establish before the heavy showers fall, or after the rains in November or December. On planting, the young plants are protected from strong winds by supports of sticks and from the hot sun by cocoanut leaves, until they strike roots and begin to grow. Hand watering is the practice followed immediately after planting. On the banks of the Ambika river in the Navsari district (Baroda State), the alluvial deposit on the river banks is particularly preferred to other soils for planting *chiku*. Planting is not done during the rains, but it is believed that if it is done in the month of May, roots of the new plants establish themselves in the ground, and do not rot when the early rains pour heavily. The spacing given varied in the past from twenty to thirty feet, but lately there is a tendency towards wider spacing. Gooty plants are used normally for planting, which is done in small pits of about a foot cube, with or without manure. The land is more or less level and loose, and no preparatory tillage is deemed necessary. Thirty feet spacing is usually allotted in sapota plantations in North and South India. In the fertile soils on the banks of the Ganges, no manures are added to the pits before or at the time of planting. In very poor soils, it is considered best in South India to add manure to the pits six months or a year ahead of actual planting. Planting is usually done in February-March, or August-September in North India, while in South India July to January is most favoured for this purpose.

Irrigation

From October, irrigation starts once in eight days in Western India. The water in the wells is generally insufficient for about two months during the hot weather. It is also brackish in many cases. Watering is, therefore, done once in ten days during this period of scarcity, with the result that a large number of flowers which open in this season drop and cause a loss, approaching forty per cent of the seasonal (Aug.-Sept.) yield. If irrigation water is available in

sufficient quantities, and if the trees are watered once in four to six days in the hot weather, it is said that there is no loss of yield in August and September. *Chiku* trees generally seem to like fairly heavy irrigation, and are not seen to suffer much in low lying areas, although stagnant water is not congenial to their best health. At Dhamdhacha and Devdha of the Navsari district, *chiku* trees are irrigated in a ring basin. A mound of earth of three feet radius and eighteen inches high is raised around the trunk of trees, with a view to protect them from violent winds which are so common especially during the early rains. This mound naturally necessitates the formation of irrigation rings, which later on merge into the broad bed system. Of course, the mound continues. Irrigation water never touches the trunk of trees, except perhaps in the very early stages, when the trees have not grown up sufficiently to require the mound. When the mound of earth has been there for some years, roots of trees freely emerge out of it on the surface and the sides. The exposure of the tip of these roots does not seem to harm the trees much. In this tract the *chiku* trees are not irrigated at all for about two months when they have no fruit on them. This period of rest is utilised for carrying out cultural operations in the plantation. In Bihar and the United Provinces water is rarely applied to sapota trees after they attain the bearing age, except occasionally during March to June, on poor soils. In the west coast of South India watering is never done to large trees, but in the east coast and central districts watering is given only to young plantations and to older trees during the hot period from February to June. On very poor and porous soils, watering is, however, done regularly according to the amount of moisture present in the soil and the amount of precipitation received. *Chiku* trees are hardy by nature and stand a good amount of water-logging at their roots. The subsoil water level in the Gholwad tract is within a foot from the surface during the rains and is generally high throughout the year. The water in many wells at Gholwad is brackish, but *chiku* trees do not at all seem to be affected by its continuous application. In some cases the surface soil develops incrustations of salt, and the health of trees is not damaged to any appreciable extent. Inter-crops of chilli (*Capsicum* sp), *Bhendi* (*Hibiscus esculentus*) and the like do suffer from such brackish water. The growers of Devdha, Dhamdhacha and Bata

villages of the Navsari district consider it beneficial to irrigate *chiku* orchards with brackish water of some of their wells. The actual analysis of this water is not known, but it is believed that the water contains a large amount of common salt. Such brackish water is considered harmful to citrus trees in the same villages.

Manuring

During the monsoon, green manuring with sunn hemp (*Crotolaria juncea*) is often practised. The usual dose of manure consists of one of the following mixtures given twice a year.

(1) Four to five baskets of sheep manure and twenty pounds of fish.

(2) Four to five baskets sheep manure and ten to fifteen pounds of bone meal.

(3) Four to five baskets of sheep manure and ten to fifteen pounds of oil cake.

Farmyard manure is substituted for sheep manure, when the latter is not available. Sometimes poudrette is given instead with great benefit. At Devdha, a *chiku* tree of ten years of age receives twenty to forty baskets of farmyard manure or sheep dung and twenty to forty pounds of castor cake. This manure is given in addition to the heavy applications made for the inter-crops. Some growers also apply upto ten pounds of common salt to each tree, although the necessity or usefulness of this is not known. It is believed in some places that common salt or water from brackish wells stimulates bearing and improves the quality of fruits. There is in this area also another practice of burying banana pseudo-stems in long trenches opened in between rows of *chiku* trees. Banana is a popular inter-crop in these plantations, and after the bunch is harvested, the best use of the pseudo-stem the growers make is to cut it and allow it to rot in the water channels, which are specially deepened for the purpose, and later covered with a thin layer of earth. Some growers even open special shallow trenches for burying banana pseudo-stems, and incorporate them thoroughly into the soil. Experiments carried out at the Poona College of Agriculture have shown that the banana stem has considerable nitrogen value as manure when properly rotten. Slaughter house refuse is also added in addition to farmyard manure or other bulky manures. Well rotten cattle manure applied as light

dressings twice a year towards the end of each monsoon is reported to be very beneficial in Ceylon.

After-care

The orchard soil is dug in September with the "Irani" foot spade, which implement is confined to Gholwad tract of the Bombay Presidency, having been introduced there from Persia by the immigrant Irani (Persian) cultivators. The spade penetrates the ground to a depth of about nine inches and turns the soil over. Basins and water channels are then made and irrigation starts from October. While making the basins, the mound of earth mentioned above is left near the trunk of the tree to prevent the trunk from coming into direct contact with irrigation water.

Inter-crops

Besides the banana (*Basrai* variety), Paul Neran variety of rose is grown as an inter-crop in a number of *chiku* plantations of Dahanu and Gholwad. The flowers of this variety are large, brilliant in colour and lasting. They thus command a good price in the Bombay market. Guavas are also sometimes planted between rows of *chiku* trees. Papayas, annual vegetables such as chillies (*Capsicum* sp), tomatoes, brinjals (*Solanum melongena*), cabbage, etc., are also grown in some orchards. Inter-crops are grown and yield income for five or six years in the early stages of plantations, and have then to be discontinued or removed in order to leave the whole orchard to *chiku* alone. Banana as has already been mentioned is a very common inter-crop in many *chiku* plantations, all the popular varieties such as the *Soneri* and *Basrai* being included. Banana plants remain in the stool for several years after planting, and yield a substantial income as well as a useful bulky manure. Besides, inter-crops of *suran* (*Amorphophallus campanulatus*), turmeric (*Curcuma longa*), ginger (*Zingiber officinale*), *tur* (*Cajanus indicus*), etc., are also grown in *chiku* plantations by rotation. Most of these crops require heavy manuring and irrigation which add to the fertility of the soil of the orchard.

Bearing

Chiku trees commence to bear fruits from the third year after planting. Some gooty plants bear fruits on them even while planting. These fruits are few, and no serious attempt is made to remove them. From the fourth or fifth year a fair income is realised, and it continues to increase from year to year until the trees are about thirty years old. In average plantations the bearing decreases after this

stage of trees. Seedling trees of *chiku* are said to take seven to eight years to come to the bearing stage. Flowers appear on *chiku* trees almost throughout the year, though blossom is more profuse in the rainy season, and less so in April and May. Fruits ripen in about six months from the time of flowering. Hence, fruits are harvested in large numbers between December and March. They gradually decrease until they become scarce in September and October. Fruits harvested in summer are generally well developed and large in size. In Ceylon the sapotas bear two crops a year, one during August and September, and the other during February and March. The former crop is the heavier of the two. Some varieties, however, fruit nearly all the year round. In the Hyderabad (Deccan) State, both the round and oval varieties of sapotas are reported to bear two crops, a year, the *Mrig bahar* and *Ambe bahar* (11). In South Florida, the season of blossoming is said to be irregular, resulting in a succession of ripening fruit throughout most part of the year. In South India sapotas become available in the market from January to May, while a few fruits are also available from August to October.

Harvesting

In the Gholwad tract, large teak-wood posts are planted all round the tree, and cross pieces are tied to them, both with a view to support the tree and its heavily bearing branches against violent winds, as well as to enable easy hand-picking of fruits from the widely spreading branches. Pickers climb up the structures for harvesting fruits. Picking is thus systematized and causes no injury to the fruit. But it requires a good deal of investment to erect these structures. As the Gholwad tract is close to forest area, the necessary teak-wood is available there cheaply as compared with other *chiku* growing regions, where this system is not prevalent.

Chiku fruits develop light yellow bloom on full maturity and shed most of the brown scaly material formed on the surface of immature fruits. When they are scratched, no latex will ooze out, and it is a matter of considerable experience to judge the maturity of the fruits before picking. Parsons (12) recommends that sapota fruits should be picked when practically ripe and kept in a dry room or shade for several days until they are soft to the touch. Fruits are col-

lected in Gholwad in bamboo baskets, which are carried by pickers on their backs. Fruits are picked with small stalks on them. Care is also taken to see that no damage is done to them while picking. At Devdha and roundabout, *chiku* fruits are picked three or four days after the irrigation turn, when the soil below is soft, but not wet, either by hand or with a stick, and are allowed to drop on the soft soil. It is the popular belief that the fruits do not receive any damage by dropping on the soft soil, sometimes even from a height of ten feet or more.

Yield

An average tree of ten years of age is known to yield 2,000 fruits per annum. The immature fruit contains tannin and latex. In taste most of the varieties are very astringent in the unripe stage. A milky latex is also found in the bark of the tree and this is known as chickle. In Mexico and Central America chickle is secured by tapping the trunks and is used largely as a basis for the manufacture of chewing gum. In other countries as in India, *chiku* is grown essentially for table purposes.

Grading

On picking, the fruits are spread out on mats under shade for a few hours in order to allow the latex, if any, to dry up. Or else the appearance of fruits is spoiled by it. Grading of fruits then follows, unless the quantity harvested is less than a basketful, in which case no grading is done. Two or three grades are commonly recognised according to the size—large, medium and small. These sizes are not standardised and they seem to vary with each grower. Fruits which are generally small are not graded at all.

Packing

Conical bamboo baskets are used in two sizes for packing *chiku* fruits. Dry leaves of banana form the packing material. These leaves are carefully preserved in summer for use in monsoon. The baskets are lined with these leaves, and on them the graded fruits are placed in layers. Even within the same lot, medium fruits are placed at the bottom, smaller ones in the middle and large ones at the top in each basket. The ends of banana leaves are then folded inside, and the basket is closed by stitching the lid on. A label is then attached to it, and the package is ready for its journey to the market. The two baskets are tied together with their closed lids face to face, and touching each other, the whole giving

the appearance of a single oval drum-shaped container. By this method, the growers save *hamali*, and other haulage charges which are levied not on the weight but on the number of packages. Moreover, this system makes the packages safer against pilferage or rough handling during transit, as the fruits inside get an all-round bamboo cover.

Bombay is the chief market for the Gholwad fruits, which are not sold to local contractors. The growers send them to their agents in Bombay direct. The agents sell the baskets on consignment basis. Long, smooth and yellowish green fruits command a higher price in the market than brown ones do. Sales are conducted in the market under cover as in the case of most other fruits. The grower receives a "*patti*" or account memo the next day, giving details of the sale price, agency charges and other market expenses. Material differences between the prices quoted to neighbouring growers on the same day for the same quality of fruits are not infrequent.

Marketing

The Bombay commission agents also send fruits to Poona, Baroda, Ahmedabad and other Indian cities. The growers of Gholwad are so much in the hands of the Bombay agents, that it pays the agents to receive the consignments from the growers and transfer them to Baroda and other markets the same way back. But it does not pay the grower to send his consignments direct to those places. An improvement in the system of marketing is dawning and the growers, realising their real loss in the original system are attempting to catch the various markets themselves. The *chiku* fruits of Gandevi area are considered to be inferior in size and quality to those produced at Gholwad. The fruits are, therefore, unable to stand competition with the Gholwad produce in the Bombay market. Perhaps the nearness of Gholwad and places in its vicinity to Bombay, also reduces the railway freight on the produce as compared with the fruits from Gandevi area and thus offers an advantage to the former over the latter. Fruits of Gandevi area are, therefore, mostly consigned northwards to Karachi and other towns in Sind and Kathiawar, where the Gholwad fruits have the disadvantage of distance.

The results of the storage trials of *chiku* fruits from the Baroda State showed that the fruit kept at temperatures 32°F to 45°F did

not ripen satisfactorily, though it remained in a hard and sound condition for forty days. The fruit of the B stage of maturity ripened normally at 52°F, and remained in good condition for five weeks. The fruits of both the A and B stages of maturity ripened well at 56°F and remained in good condition for about a month (6). It has been shown that green *chiku* fruits can be kept for one month at a temperature between 40° and 50°F, after which they ripen normally on removal from the cold storage. Smith (14) from Jamaica states that unripe sapotas were stored successfully for sixteen days at 45°F. Wardlaw (15), however, finds that, at Trinidad the range between 45°F and 50°F was less favourable. Gonzalez (8) in Philippines has recorded that mature fruits held at 32°F and then removed to about 85° ripened normally. Ripe fruits which usually keep for three to four days can on the other hand be stored successfully for two weeks at 32°F. Campo (4) found that for both green and mature fruits, the best storage temperature was 59°F, the fruits having been successfully stored at this temperature for eighteen and sixteen days respectively. At 32°F, ripe fruits were held for twelve days at which temperature green fruits could not be stored for more than five days.

Cold storage trials

No attempt has yet been made to preserve *chiku* fruits either in cans or as other preserve in Western India. This question is attracting attention in recent years, because fresh fruit does not fetch a remunerative price to the growers. The fruit is a poor keeper too, and hence it cannot be sent to distant markets. It would, therefore, be essential to evolve methods of preserving it in various forms, and to transport it in refrigerated vans to distant markets in order to extend its cultivation. In the Vizagapatam district of the Madras Presidency, a small canning firm has canned sapotas in sugar syrup as a trial measure. The product when sampled was found to be excessively sweet. Further trials with syrups of varying strength are now being carried out. In some parts of America, sherbats of sapotas are said to have been tried. Jams, sherbats and canned fruits in dilute syrup are some of the products of *chiku*, that are believed to be possible and merit further detailed investigations.

Preservation

Three analyses by Chace, Tolman and Munson (9) of the flesh of Cuban Sapotas, designated mamey colorado,

Chemical composition

and one analysis by Pratt and Del Rosario (7) of the flesh of Philippine sapotas designated Chico mamey, are shown in the following table:

	Flesh in fruit	Solids total	Solids insol	Protein	Acids as citric	Sugar re-ducing	Sucrose	Ash total	Ash Alk.*
	%	%	%	%	%	%	%	%	cc.
Cuban	75	30·99	6·55	1·09	0·13	11·97	9·03	0·84	60
Philippine	70	31·2	9·7	1·23	0·18	8·52	8·00	1·26	119

*cc. N/10 acid per 100 grammes pulp. Quoted by Winton and Winton (16).

Adriano (1) reports the following results on the flesh constituting 81% of the fruit-solids 15·45, protein 0·60, fat 0·14, fibre 0·81, nitrogen free extract 13·47 and ash 0·43 per cent.

Chace (9) found 0·80 and 0·89% of ash in the flesh of 2 samples of Cuban sapota and the amounts of mineral constituents in the ash were:

	K_2O	CaO	MgO	P_2O_5	SO_3	Cl.
	%	%	%	%	%	%
I	50·57	1·38	1·36	4·90	3·54	17·34
II	48·20	1·73	3·35	9·66	3·80	16·00

*cc. N/10 acid per 100 grammes pulp. Quoted by Winton and Winton (16).

The chiku tree is comparatively free from diseases and pests caused by fungoid organisms and insects. Recently, however, a fruit borer (3) which is not yet studied is seen to attack the fruits generally at the point of contact of two or more fruits, when they are borne in bunches. Singly borne fruits are also attacked by it.

Diseases and pests: fruit borer.

No remedy is yet available to combat it. The stemborer (*Arbela tetraonis*), is a minor pest. The borer should be extracted out or the gallery treated with carbon bisulphide or some volatile material and the opening plugged and plastered.

Stemborer

Mealy bugs (*Phenacoccus icervoides* Gr.) attack tender shoots of *chiku* trees in large numbers, and deface the fruits. Spraying with kerosene oil emulsion or fish oil soap is effective against this pest. In South India this insect becomes occasionally a serious pest and it has been recommended that pruning of badly infested shoots and spraying with a contact poison are the successful control measures.

Mealy bugs

Scale insects of greenish yellow colour and more or less of sedentary nature are sometimes found on the tender leaves and shoots of sapota trees. Gradually these insects devitalise the plants and cause the development of an unsightly coating of sooty mould as an after effect. Early spraying with a strong contact poison controls the pest. When the sooty mould has developed, spraying with half per cent Bordeaux mixture to which starch paste has also been added, serves to liberate the mould in flakes.

Scale insects and sooty mould

Galls are often formed on the stems of *chiku* trees. Several galls may be seen on a single tree. The gall seems to be a hereditary malformation. It retards the growth of the branches above, and affects their bearing capacity. Tender root tips emerge from the base of the gall as in the case of a gooty plant. Gooties obtained from galled trees, are known to form galls on them. Being a hereditary physiological trouble, it seems to be incurable. Selection of scions from healthy trees appears to be the only possible preventive measure at present against galls.

Galls

Flower shedding seems to be one of the most serious physiological troubles with this fruit tree. Exactly what causes this phenomenon is not possible to say at present as no study of this question has as yet been made.

Flower shedding

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CHAPTER IX

FIG (*Ficus Carica* L.)

The district of Poona is the chief centre of fig cultivation in the Bombay Presidency. Even there, plantations are restricted to a very few places as for example, the Purandhar and Saswad talukas. The total area in the Province of Bombay is 1,230 acres (1945). Leading fig growing countries are Italy, Spain, Turkey, United States of America, Greece, Algeria and Portugal, total acreage in the world being 1,625,000.

Introduction

A few acres of fig are also found in the district of Ahmednagar and Satara, which adjoin the Poona district. Lately the cultivation of this crop is being attempted on a limited scale in other parts of the Presidency such as Gujerat. In the district of Poona, the fig crop was bringing a fair return to the grower until the recent appearance of the serious disease of rust. The havoc played by this disease is so great that growers are actually destroying their affected plantations, and replacing them by those of *Santra* and *Mosambi* oranges. Fig, however, is a very delicious fruit and it promises to spread out to new regions and as the control of rust becomes more effective by the efforts of the Bombay Agricultural Department, its cultivation is bound to prosper.

The orginal home of the fig tree is the Mediterranean coast. Fig cultivation is found in several countries of the temperate zone, such as Spain, South of France, Italy, Greece, Asia Minor, Afghanistan, Florida, Texas and California. In Egypt, fig cultivation is limited. Generally everywhere effort is being made to increase and improve fig cultivation. In India, besides Poona, fig is cultivated on a limited scale round Sahranpur in the United Provinces, Bangalore and Penukonda in South India. In Northern India, fig cultivation is hindered by serious attacks of the stemborer. Lately the Mysore Government is taking active interest in the extension of fig plantations as a part of their rural development move.

Origin and distribution

In Greece, an organisation known as the Office for the protection of Greek figs is mainly responsible for its improvement. Asia Minor exports to other countries about 75,000 tons of dried figs annually, and the authorities zealously protect the secrets of its cultivation by prohibiting its study by foreigners. In the Western districts of Morocco, there are over 1,600,000 fig trees which are subjected to taxation. California in the United States of America produces as much as about 5,40,000 boxes fresh and 10,000 tons dried figs annually, the total being valued at 920,000 dollars (1928). In Egypt, the fig industry is not quite self-sufficient. This country imports for internal consumption dried figs worth about £50,000 annually in addition to its indigenous production of fresh figs.

Varieties and classification

The edible fig belongs to the genus *Ficus* of the Natural Order Moraceae. Generally two distinct types of figs are recognised in commerce, the edible fig and the caprifig. The latter is a male type. Its fruit harbours the fig wasp called the *Blastophaga*, which is the chief agent to transfer pollen from caprifigs to edible ones. Hence the economic importance of the caprifig, although its own fruits are of no direct utility. Edible figs are mainly grouped into two divisions, the Smyrna figs and the Adriatic figs. Smyrna types such as the *Lob Ingir*, *Kassaba* and *Eisen* require caprification or pollination by the *Blastophaga* insect, without which they cannot develop mature fruits. The successful cultivation of these varieties, therefore, depends upon the rearing of the caprifig trees. On pollination, fruits of these varieties generally develop seeds. They also contain a high percentage of sugar, on account of which the fruits lend themselves easily to drying and keep well for a long time. Unlike the Smyrna figs, the Adriatic figs develop without caprification. The type grown in the Poona district and what is known as the Coimbatore in Baroda and parts of Gujerat, belongs to this group. A large number of varieties grown in the South of France, Italy and Spain are Adriatic types. Fruits of these varieties are good for the table. Some of them such as of the *Kadota* can be dried also. Only three classes of figs are known on the basis of flowers borne within the receptacle, namely, Common figs, Smyrna figs and Caprifigs. Most of the innumerable varieties

of figs grown in Europe and America are grouped under the first class. The development of fruits in this class is somewhat analogous to that of navel orange and the banana, the female flowers remaining unpollinated, and the fruits, therefore, being seedless. The apparent seeds are hollow shells without the inner kernel and germ. The Mission and Brown Turkey are two important varieties of this group. Smyrna figs have long slender styles as common figs have, but they require the stimulus of pollination to enable the fruits to set. Without the stimulus the flowers soon turn yellow and drop. Common figs can produce fertile seeds when caprified, but caprification is not necessary in their case for setting fruits. Caprifigs are mostly inedible on account of presence of insects and a mass of dry male flowers within the eyes. They set fruits only when stimulated by the *Blastophaga grossorum* by laying eggs and developing larvae within their gall flowers. In classifying the various varieties of figs, Bobone (1) attaches importance to fruit characters like shape and size of fruits, colour of skin, roughness of surface, colour consistency and flavour of flesh, length of peduncle, etc. On the basis of these characters, he described 52 varieties which according to him, are grown in Portugal alone. Grasovsky (20) described about 40 varieties grown in Palestine. In Italy Ravasini (27) describes 50 varieties as grown in that country. In India, a type of Adriatic fig of high quality and perhaps originally introduced at Coimbatore, is becoming popular in the Baroda State and other parts of Western India. It is locally known as the Coimbatore fig and is considerably superior to the Poona type. Several fig varieties, namely, Poona, Bezwada, Ganjam, Bangalore, Myceram, etc., have been tried at the Fruit Research Station, Hassarghatta, Bangalore. Bezwada variety seems to be very productive. Bezwada variety on *Ficus Palmata* stock has given good yield.

Soil

In the Saswad taluka of the Poona district, the soil in which fig trees are cultivated successfully is medium black with a large admixture of lime nodules in it. Plantations are generally located on the sides of hills and near *nallas* (streamlets), which permit a thorough drainage of the soil. Plantations which are open to high winds do not seem to suffer on that account. Especially in the summer months, the

plants perhaps benefit by exposure to winds. Near Surat at Sachin fig trees are found to thrive well. The soil of this area is similar to that of Saswad, but the rainfall is nearly double. The Sachin soil is, however, much deeper than that of Saswad, being ten to twelve feet deep as against two to four feet at Saswad. On the Baroda Government Farm, where the soil is light loamy and very deep, fig trees of both the Poona and Coimbatore varieties are found to thrive. The Poona type bears less and smaller fruits, while the Coimbatore produces large fruits of high quality. In general, fig trees seem to be more sensitive to climatic conditions than to soil. They are seen growing well practically on all kinds of soil, provided there is an adequate supply of water during the fruiting seasons. They do best in alluvial clay loams, as such soils are well drained and conserve enough moisture. Sandy soils are not quite good for fig trees, unless they are supplied with enough organic matter and lime. The presence of these ingredients in sufficient quantities is essential to induce fruiting. In Asia Minor a soil which is considered best suited for the cultivation of fig trees has the following composition:

	Sample 1.	Sample 2.
Stones on fine matter	26·90	38·99
Moisture	0·22	0·28
Organic matter	2·56	2·80
Nitrogen	0·04	0·06
Calcium carbonate	0·60	0·60
Phosphoric acid	0·28	0·28

In Greece, it is stated that the fig tree is not exacting in its soil requirements, but shows a preference to a soil which is cool, deep and not too light. Borg (3), in the Maltese Island states that the fig can grow on all soils which are free from stagnant humidity. It has got a powerful root system and hence delights in deep soils especially where there is a deep broken or porous subsoil. Sandy soils with an adequate amount of lime and organic matter produce fruits which are high in sugar contents and are superior in colour after drying. A red loam with a limy substratum and about three feet deep is considered the best for figs in the fig growing tracts of South India.

The fig is chiefly a fruit of the sub-tropical and temperate regions, although several writers have classed it as exclusively a

sub-tropical fruit. The climate of the Deccan, and in fact any part of Bombay Presidency, does not appear to be ideal for its health and growth. As in the case of grapes, figs in this tract bear a good crop during winter, the crop ripening in the months of March and April. The fairly cool nights of the winter months help the fruits to harden up. The quality of ripe fig is, however, good and marketable, though it cannot equal that of the Smyrna figs. Effort is, therefore, being made to preserve and extend fig plantations in this tract as far as possible. Though low temperature is not harmful to fig trees, a hot and moist climate is. Even humidity may not matter if the temperature is sufficiently low. Smyrna trees are more sensitive to climatic conditions than Adriatic ones. The former are confined to regions where winters are sufficiently mild in order to enable the *Blastophaga* to live through without injury. Warm climate is necessary for growing figs meant for drying purposes. There should be no rain or heavy dew-fall to enable the fruit to become dry and hard. Cold nights during winter help fruit to become dry and hard, while they retard the formation of sugar in them. Severe cold makes the bark of trees crack. In Africa young branches of trees are besmeared with cowdung to protect fig trees against frost. Rainfall affects the fig crop considerably, especially under the conditions of the Bombay Presidency. Where rainfall is scanty, the crop is more successful than where it is heavy. The Saswad area which is a plateau has a rainfall of 14 to 20 inches per annum. The climate is dry and warm during the fruiting season. Still, occasional showers during the months of April and May damage ripening fruits considerably. Rain-beaten fruits are insipid in taste. Rust is encouraged by cold winds following heavy showers to the detriment of the crop. The fig trees go to rest during the rainy season in the Deccan and these trees thus become leafless, while most other trees put forth new growth. It may be that the leaves drop due to rust caused by rain. While the heaviest rains are restricted to June to October, the months of December to March are practically dry and helpful for the development of fruits. Unusually warm weather when the immature figs are developed causes the fruits to drop. Some varieties like Kadota fig are stated to be particularly affected by high temperature in June

Climate

and July in California. Proper attention to soil moisture is said to minimise this loss. Frost also affects young fruits, growth and crop disastrously, and weakens dormant fruit buds. An equable temperature during growing and fruit developing periods is, therefore, essential for successful fig culture. In Asia Minor it rains practically throughout the year, the average rainfall being about two inches per month, except during the months of July and August which are dry. This dry period is congenial for ripening and drying of fruits.

Propagation

Propagation of fig trees by the use of cuttings is the most common method employed in all fig growing countries of the world. Cuttings are taken from terminal branches, which are about one year old. Such cuttings have short internodes, and they yield a high percentage of success, and produce vigorously growing plants. Cuttings are planted in nursery beds at the commencement of the rains. They become ready for planting out into the field in the following year. It is easy to propagate the fig tree by layering and gooty also. As the tree is vigorous and productive on its own roots, it is not necessary to resort to the use of a rootstock. After planting cuttings, care should be taken to remove air-pockets by working the soil in between the cuttings. Grafting of fig trees can also be practised with some success. But this method is not much employed. By grafting it is possible to convert established inferior trees into better ones. In South Australia, fig trees are grafted by side grafting, but the benefits of this operation are not clear, excepting top-working unproductive trees with improved types. The Poona fig can be budded on *Umber* (*Ficus glomerata*) and it was also found possible to side-graft cultivated fig on *Ficus glomerata* at Kodur, but this method is not worked out sufficiently to prove its advantages, which might emanate from the use of hardier, root-stock plants. Cleft grafting can also be practised if care is taken to exclude air and may be done during the early spring (7). Also cuttings are taken from one-year-old wood which is stocky, smooth and short-noded. The length of cuttings depends upon the nature of the soil, being 30 to 40 cms. in sandy soils, and much less in heavier soils. Seedling plants are also raised using seeds which sink in water, but as they vary in the quality of fruits they produce, they are not commonly

planted. In Greece fig trees are propagated by layering, mature wood of about two-year-old being employed for this purpose. When cuttings are used they are planted upright and covered with soil, so as to bury the terminal bud to a depth of two to three centimeters. Borg (3) states that budded or grafted trees of fig are more vigorous and produce finer fruits than trees raised by layering or cuttings. Although cuttings can be planted out in the field soon after rooting, they are allowed to remain in the nursery for about two years to become strong. Grafting is generally done in February and March, and budding in March to September.

When budding, the ring method may be adopted on small rootstocks (7), and the patch or shield methods for larger ones. One to three-year-old branches can be top-worked by shield budding at the time when their bark slips easily. Buds should be cut larger for older branches. Usually, cleft and rind grafting are adopted for top-working fig branches of three to four inches in diameter. The scion used is two-year-old with three or four buds. Scions and stubs are protected by perforated paper collars, and the limbs are white-washed to prevent sun-burn.

In the Madras Presidency the demand for fig plants raised by layering and gooty is greater at present than for rooted cuttings. Cuttings are believed by some of the growers to be more liable to the attack of white ants than layers. Suckers which appear at the base of trees make good planting material, especially if roots are developed on them.

When the site for raising a fig plantation is selected, the land is cleared of all brush wood and wild growth, ploughed and harrowed several times, levelled and got ready for taking pits. Spotting of the pits depends upon the spacing adopted. Spacing of fig trees depends upon several factors such as the texture of the soil, growth habit of the variety and the form of cultivation desired to be adopted.

Spacing and planting

Spacing is, therefore, found to range from 8 to 10 feet each way in Palestine, 40 ft. in Africa and 60 ft. in Smyrna. The usual spacing allowed to fig trees in the Bombay Presidency is fifteen feet each way. The plants remain as bushes and do not grow tall. If the spacing is increased to 18 to 20 ft. it faciliates inter-culture in the plantation. At present, with 15 ft. distance, all cultural

operations are carried out by manual labour. Pits are dug at the required distances, their size being one and half to two feet cube. It seems desirable that the preparatory tillage is completed and pits are taken during the summer months before planting, so that the pits can be left exposed to the sun and wind for weathering for sometime. Just before the advent of the rains, pits are filled with their original soil, mixed with about eighty pounds of cattle dung manure. While filling the pits, the original soil is reversed as in all cases of fruit planting in the region by placing the top half at the bottom and the lower half on the top. The soil is well pressed on filling, layer by layer. When the soil is fertile or where there is danger of white ant attack, manure should not be added to the soil in the pit at the time of planting. When the rains start and the ground is thoroughly wet, planting is undertaken. One or two rooted cuttings may be planted in each pit, burying only the root portion in the ground. Soon after planting, the plants are watered well. If rains do not intervene, watering is repeated every week until the plants are established and begin to grow.

Manuring

In the first year, one basket or about twenty pounds of old well rotten cattle manure or sheep dung is given to each plant. It is gradually increased to five to eight baskets when the plantation is eight years old, and then maintained at that dose per annum. Oilcake, ash and bone-meal manures are also being given lately in varying quantities in order to encourage good yields. Manures are given generally at the start of the monsoon, during the first two years of the plantation. But when the tree is treated for the crop (*bahar*), manure is applied about the end of September, when after the trees have been rested, water is given to them. Night soil is applied to figs by some growers in Bangalore after mixing it with red earth and sand. Sewage effluents have also been used with benefit for fig near Bangalore. Tannery refuse is also said to be popular in some places. Most of the fig growers in South India believe that a mixed manure made up of sheep dung, cattle manure, red earth and sand is required for successful fig production. Organic manure is usually applied in the dormant season of the trees, while fertilizers are applied late in spring or summer. The best time for applying manures seems to be when new growth starts.

Fig trees in the Deccan require irrigation throughout their lifetime between October and May. During the rains, they are not watered, as that is the season for them to rest. Curiously enough, fig trees shed their leaves and stop growth in August and September in this region. About the end of September or early in October, they are manured and irrigation is resumed for the winter crop. Where for want of water or for other reasons irrigation is given once a fortnight or so, fruits are seen to develop to a larger size and become sweeter than in places where water is given more frequently. After the rest, irrigation is given sparingly and increased gradually in about three turns. Fig orchards being of very small sizes in some parts of South India, are mostly watered by hand, at intervals of three or four days. Too much water is said to make the fruits insipid, while its deficiency renders the fruit small and hard.

Irrigation

In countries like Asia Minor (6),, where rainfall is steady and well distributed throughout the growing period, artificial irrigation is dispensed with altogether. The cultivation of fig trees, therefore, becomes less expensive. In Poona, the trees require ample water during the hot weather when fruits ripen. This factor considerably adds to the cost of production of fruits. In California, fig orchards are irrigated only when the soil is dry. Abundant irrigation to trees is said to lower the quality of fruits produced. It has been observed that fruits collected after a dry period are less sour than those collected immediately after an irrigation. During the early years of the fig plantation, inter-crops of vegetables such as beans, peas and *matki* (*Phaseolus aconitifolius*) are grown. No inter-crop of the type of *jowar* (*Andropogon sorghum*), brinjal (*Solanum melongena*), chillies (*Capsicum* sp.), tomatoes, etc., is grown.

The fig plants have a tendency to put forth new shoots from all their buds, especially when they are young and vigorous. This results in a large number of shoots springing from close to the ground and often from under the ground and makes the plants bushy. The Saswad cultivators allow all these shoots to grow under the impression that the larger the number of shoots the greater is the yield. It is also considered that the trees with a number of shoots rising

Training and pruning

low can resist strong winds. Further, in cases of stemborer attack or other troubles the attacked branch may be pruned off, leaving part of the tree at least in tact. Observations have shown that the lower shoots can be nipped in the bud and a strong, single stemmed tree can be raised with several advantages. If the tree has a clear stem upto about three feet from the ground, operations of cultivation can be carried out with bullock power and plantations can be kept clean. With judicious pruning and notching on the single stem, a well balanced tree can result with normal productivity. The stemborer trouble is minimised in a clean grove, and any such attack can be at once detected and treated from the beginning. If fig trees are headed back to 18″ to 24″ at planting time, leaving only three to four well developed and evenly placed side branches all round the plant, proper shape of the tree and strength of the framework are ensured. Periodic examination will be necessary in the case of such trees in order to prevent the growth of unwanted shoots and vigorously growing suckers, which tend to crowd together in a few parts particularly near the pruned regions. Attempt has been made to turn fig trees in a trellis fashion but although this method seems to be successful in producing a fine hedge or border row in the plantation, its economic or commercial possibilities are doubtful.

In the Deccan, fig trees are grown by the cultivator as shrubs, and not much of pruning is practised. Pruning when done is very light. During the earlier stages only too much crowding is relieved, and when the annual growth slackens down later, severe heading back induces fresh growth and is followed by light pruning. On the Jagudan farm (Baroda State) excessive vegetative growth which was sterile was heavily pruned back, with the result that new fruit bearing shoots were produced. On the Baroda Government Farm also pruning has induced fresh fruit-bearing spurs.

In several countries pruning of fig trees is practised in order to admit light and air and to prevent crowding up of branches and to improve shape of trees. Sterile twigs found at the base of main branches are cut off annually. The centre of tree is thinned out. In case trees are not evenly balanced, branches on the larger side are pruned back to establish a balance. There are two systems of pruning. One is the winter pruning and the

other, the summer pruning. The effect of the former practice during the dormant period of the tree, is to stimulate growth when the tree returns to vegetative activity. The latter reduces the absorbing and elaborating plant parts and retards growth considerably. Old fig trees are renovated by shortening the main branches to a stump in winter. For Adriatic figs, thinning out and occasional heading back is said to be useful, in forming a good amount of new wood. In the case of Kadota figs, trees are headed very low and the new branches are thinned and pruned back every year, so as to produce low headed open-centred tree. Caprifigs are not pruned so drastically. Heavy winter pruning of unfruitful fig trees is practised in California, especially in Kadota and Brown Turkey varieties and the Magnolia in Texas, to stimulate a heavy vegetative growth, bearing later in the season a second crop of figs in abundance. Such heavy winter pruning is not, however, advocatd when the fruit crop of figs is desired, as pruning will result in a loss of the wood bearing dormant fruit buds. Heavy summer pruning is practised, but this is said to be undesirable. Sometimes, fig trees are planted and trained for two forms—the shrub and the tree. In the shrub form, pruning back of current season's growth is found to increase the yield by about sixty per cent. In the tree form, pruning is done first for training the young tree and later for improving the yield in old trees. The main object of pruning in both the cases is to build up a strong framework to enable the limbs to carry on the yield of fruits without damage to the health of the trees.

At Bangalore the fig tree is allowed to grow straight to a height of about three feet and then it is topped (34). This induces it to branch out. The branches ultimately reach a height of about seven feet. But topping is not practised in Bellary and Penukonda in South India. In fig trees the wounds caused by pruning do not heal up quickly and as a result premature decay occurs, especially when stumps are left at the base of the pruned branch. Small or secondary branches should be neatly pruned at a point where side branches occur.

Want of sufficient knowledge of the systematic methods of pruning in the Deccan results in the trees assuming scraggy forms, though they were properly trained in the younger stages. This led to trials in notching on branches to induce dormant

buds to produce new shoots locally and increase the bearing area, at the same time maintaining a proper form of the trees.

Notching

Notching consists of removing a small piece of bark one-sixteenth to one-fourth of an inch broad, and about an inch long, in a slant manner immediately above the dormant bud which requires to be stimulated. The wound so caused produces a flow of latex. Care should be taken to prevent the latex from accumulating and drying upon the surface of the bud, as this would retard the growth of the bud. This notch checks the free flow of sap and stimulates the bud just below it. The bud sprouts soon and grows to a length of about two feet in about three months. It is not desirable to notch more than two buds a year. The basal buds on a branch do not respond to this practice satisfactorily, while healthy and well developed buds on the middle part of the branch do. Several authors have advanced their views on the effect of notching upon the health of the plant, but the question seems to remain yet a disputed one. There is no unanimity of opinion with regard to the salutary effects of notching. Some workers have stated that certain inhibitory substances flow down through the bark and check the growth of buds, while allowing a few buds at the top to continue growing. If this is true, the stimulus of notching on the sprouting of dormant buds becomes clear.

Bearing and harvesting

A few fruits may be produced on fig trees in the first two years, but they are not allowed to develop, lest the strength and health of the plants be undermined. Fig trees begin to bear a crop from the third year of planting in the Deccan. A good and steady yield is obtained from the fourth year onwards. Fruits ripen from March to the end of May. In South India, fig trees bear twice a year, namely, July to September and again from February to May. Fruits produced in the hot weather are more valuable as they are good and sweet. In the Saswad area, when fruits are intended for transport to distant markets like Madras, they are picked when yet slightly immature, in order that they may reach their destination in good condition. The yield of figs varies considerably from locality to locality. In the Saswad area, the average yield from a healthy tree is about forty to fifty pounds per annum, and with 200 to 300 trees per

acre about 10,000 lb. of fruit may be realised from one-acre plantation.

In Egypt, some varieties of fig bear fruits twice a year. The first crop is ready for harvest late in June, while the second is ready in September and October. The fruits are harvested every third day in strong containers which prevent injury to them. The yield obtained from fully grown average trees is forty to fifty pounds each per annum. In Hawaiian islands, ripening continues throughout the year. But the main season is May to July. In California, the fig trees produce two crops a year. The first crop appears on the old wood, the fruit buds pushing out during the spring, and fruits maturing from May to July. The second crop is produced on the axils singly on the wood of the present season and ripens from July to November. In some parts, even a third crop is produced, which continues to ripen as late as early January, but this is only a continuation of the second crop. Individual trees bearing little or no first crop, or only first and no second crop, or good crops of excellent quality in both the seasons are found growing in one and the same orchards. Wardlaw (36) states that figs should be harvested when of a light green colour and soft to the touch. Gould (19) and Stansel and Wyche (33) recommend that figs should be picked full grown but just prior to softening. Fruits are picked with about an inch of stalk on them. In humid and warm regions, figs cannot be allowed to ripen on the tree as in warm and arid regions, lest a part of the crop goes to waste.

The nature of flowers of fig trees is found to be different in different varieties. Among the various types known, four distinct kinds of flowers are met with. They are staminate, pistillate, gall and mule flowers. Staminate flowers are found in caprifigs. Stamens vary from one to five in number with an average of four. Pistillate flowers are found in the Smyrna figs and generally in all edible figs. The ovary is superior with a bent style, which is much longer than the ovary. The female flowers are practically the only kind borne within the receptacle of edible figs. Gall flowers are modified female flowers and are capable of producing seeds, and are found only in caprifigs. The ovary of these flowers harbours the eggs and larvae of the *Blastophaga* insect which is the chief agent in trans-

Caprification

ferring pollen from the caprifigs. Mule flowers are imperfect flowers found in edible figs. They neither develop seeds nor breed the *Blastophaga* insect. These variations in the nature of flowers have caused the development of an interesting horticultural practice known as caprification in fig culture. This process consists of suspending about fifty fruits of the first crop of the wild caprifigs on the branches of edible types of the Smyrna groups. Adriatic varieties do not need it. The object of caprification is to encourage the production of seeds in the edible figs by fertilising their flowers, with pollens of caprifigs, so that their fruits set and mature. The act of pollination is actually performed by an insect called *Blastophaga grossorum*, belonging to the wasp family. This insect carries the pollen of caprifigs into the fruits of edible types. Only fruits of caprifigs which are called "*Profichi*" and which contain the wasp are of any use in the process of caprification. Caprifigs are strung into a wreath and suspended on the branches of edible varieties. Fruits are also suspended in small baskets made of one inch wire-nettings. When fruits attain the size of a marble, they are considered fit to receive pollination through *Blastophaga*.

The actual process of pollination by *Blastophaga* is interesting. Shortly after the *profichi* (caprifigs) are suspended, the female *Blastophaga* hatch out of their galls, and in their effort to leave the fruit, they get covered with the ripe pollen. Once out of the caprifigs, the insects search for other fruits to lay eggs in. But when they do not find caprifigs, they enter edible figs for doing so. In this act, they unintentionally pollinate the flowers of the edible figs, which are then induced to produce seeds and to develop in size and mature. Thus caprification is but an artificial process of pollination accomplished partly by man who suspends the caprifigs and partly by the *Blastophaga* which carries the pollen to the flowers of edible figs. The summer broods of *Blastophaga* are usually ready for issue from the caprifigs about the middle or end of December. As has already been stated, caprification is not necessary for Adriatic figs and is not practised in the Bombay Presidency.

In the Poona district, figs are packed in conical bamboo baskets, which are narrow at the top and broad at the base. The baskets cost two annas each and hold nearly fifty pounds of fruit. Figs meant for distant markets like Bombay or

Madras, are packed in smaller baskets of about ten pounds capacity. While packing, fig leaves are spread inside the basket and fruits are laid carefully in layers on it. There is better selection of fruits meant for Bombay than those meant for Poona. Fruits are sold locally to some extent, but in that case they are very well sorted out and graded. Prices are fixed on these grades.

Packing

In California, figs are packed in small boxes, lined with paper, corrugated card boards being used to separate the several layers in a package. In Smyrna, fruits are harvested when they are ripe but still hard. Fruits of the choice grade are packed in wooden boxes of 12″ by 16″ size, with a depth corresponding to the thickness of the large sized fruit. Fruits are packed in single layers in it. The rows of fruits are protected side-ways by white papers from touching and damaging one another. The box is also lined with paper. Fruits of varieties which have thicker skin are packed in smaller boxes but in double layers. Fresh figs being very delicate, require careful handling.

Australian figs were successfully stored at 50°F for twenty-one days (38). Wilcox and Hunn (37) report that ripe figs may safely be held in cold storage at 32°F for about a month.

Transport

Figs are transported in Bombay Presidency to the market either in bullock carts or in motor buses. These vehicles are used upto the railhead in cases of transport to distant markets. Half of the fruits produced in the Saswad area is sent to the Bombay market. Of the remaining half, nearly eighty per cent goes to Poona and the rest to other markets like Madras in the South. The prices of figs vary from month to month, ruling high when fruits just come to the market in the beginning of the season. The prices are very low during April and May when the fruits glut the market, slightly recovering at the tail-end of the season before the rain starts.

Food value

Figs have a very high food value owing to their proteins and carbohydrate contents and high laxative properties. The average composition of the edible portion of fresh figs indicates 79 per cent moisture, 1·5 per cent protein, and 15·51 per cent total sugars. The analysis of Poona figs shows that they contain 75 per cent of

Work carried out in India on the analysis of Figs shows the following results:—

Figs	Name
Ficus carica	Botanical Name
89·8	Moisture %
1·3	Protein %
0·2	Fat (Ether Extractives) %
0·6	Mineral Matter %
—	Fibre %
17·1	Carbohydrates %
0·06	Calcium %
0·03	Phosphorus %
1·2	Iron mgs. %
75	Calorific Value per 100 gms.
270	Carotene (I. Unit Vitamin A. per 100 gms.)
—	Vitamin B_1 (1.U per 100 gms.)
2	Vitamin C (mgs. per 100 gms.)
21	Calories per ounce

According to Read, etc. (28), the chemical composition of Fig in Shanghai is given as below:—

Fig. (Foreign)	Fig. (Chinese)	Name
80	74	Edible portion %
82·05	83·62	Water %
0·98	0·99	Protein %
14·85	12·58	Carbohydrate %
0·81	0·44	Fat %
0·76	1·92	Crude Fibre %
73	60	Calories per 100 gms.
0·53	0·45	Ash %
0·051	0·049	Calcium %
0·029	0·023	Phosphorus %
0·0013	0·0004	Iron %
0·172	0·180	Potassium

moisture, 15·20 per cent reducing sugars, and 2·1 per cent non-reducing sugars. A sample of dried Poona fig gave the following analysis:—

Ash	3·2	per cent
Ether extract	0·7	,,
Proteins	4·7	,,
Digestible carbohydrates ..	89·3	,,
Woody fibre	2·1	,,

Hawaiian figs are a good source of calcium, poor source of vitamin C and a fair source of vitamin A. Brown Turkey fig of Hawaii was found to be a fair source of vitamin A, B and G and a poor source of C (25). (See pages 395, 396 and 398.)

Winton (39) analyses the edible portion of fig as follows:—

Total solids 14·98%; Solids insoluble 2·37%; Protein 1·40%; Citric Acid 0·21%
Invert sugar and sucrose 10·80% Total ash 0·49%

Diseases and pests: Leaf eating caterpillar

The leaf eating caterpillar, *Ocinara varians* W. is often a serious pest of fig trees in the Deccan, and this pest attacks wild varieties of figs also. Hand picking is possible and effective specially on small plants. Spraying with lead arsenate at a strength of one ounce in 3 gallons of water or D.D.T. at 0·2 is quite effective.

Stem borers

Stem borer, *Batocera rufomaculatus* Lin. is another common and serious pest on young fig trees. It also attacks other trees, namely, mango, guava and pomegranate. The insect bores into the stem and may ultimately kill the plant. The presence of grass outside the hole indicates the attack. By way of control, the insect may be extracted by means of a thin hooked wire, or may be killed inside by injecting a small quantity of chloroform or carbon bisulphide and closing the hole with mud. Where there is much danger of attack, it is recommended that the trunk of the tree be protected with paper painted with coal tar or with $\frac{1}{16}$th inch mesh wire-gauze.

Mites

Mites are also occasionally found to attack the leaves of fig trees causing them to look scorched. Spraying the leaves with lime sulphur wash is the effective control.

Daniel and Munsell (13) reporting on the quantitative data on vitamin content of this fruit reveal as below:

Fresh Fig	Vitamin A	Vitamin B	Vitamin C	Vitamin D	Vitamin G
Brown Turkey ..	80 (Int)	10 (Int)	5	—	33
Frozen					
Mission	100 (Int)	—	0	—	—
Adriatic	—	33	0	—	—
Lob Inger	50 (Int)	—	3-5	—	—
Drid Unsulphured					
Lob Inger	1/5th of fresh	—	—	—	—
Sun dried, Adriatic ..	50 (Int)	50 (Int)	0	0	40
Sun dried, Mission ..	50 (Int)	—	0	—	33-50
Sulphured					
Lob Inger	30% fresh	—	—	—	—
Sun dried, Adriatic ..	—	23 (Int)	0	—	50
Sun dried, Mission ..	78 (Int)	—	—	—	33-50

Int. means International units and others denote Sherman units.

Rust

Fig trees are susceptible to the disease called rust, caused by the fungus, *Cerotelium fici*, which appears as brown spots on the leaves. Heavy rains followed by cold winds during December to March, when fruits develop increase the disease. The affected tree is defoliated and fruits drop prematurely, thus causing heavy loss of the crop. This disease has not yet been effectively controlled, although sulphur dusting checks it and minimises the loss of fruits. 5: 5: 50 Bordeaux mixture is an inexpensive and efficient treatment, not only holding the trouble in check, but eradicating it in two or three seasons. In America, fig rust has been diagnosed as rusty brown spots with pustules containing powdery spores on the under side of leaves. Affected leaves soon become dry and ultimately drop. Timely spraying with 5: 5: 50 Bordeaux mixture is found to control the trouble.

Die-back

Die-back or the dying back of young shoots of fig trees in early winter, has been noticed in the United States of America. This occurs on weak and straggy trees, which have been injured in the previous winter. This trouble is overcome by suitable manures and resting of trees. A virus disease of fig is recorded from many places in New Zealand. Symptoms of disease resemble those of *Ficus virus*. Symptoms are seen both on leaf and fruit and the virus may be responsible for premature dropping of figs. The virus has been successfully transmitted by grafting and budding (24).

Fruit drop

Fruit drop is a common trouble due to physiological causes. Unfavourable climate seems to be the chief factors causing it. Fruit shedding is attributed to excessive dryness and heat, cold nights, cold winds and light frost, or moisture deficiency, in which case fruits which escape shedding develop very poorly and are insipid in taste. Shedding of figs is also seen to occur in uncaprified Smyrna figs due to lack of pollination.

Sun-burn

Sun-burn, which gives rise to disease in fig trees is seen particularly on newly planted young trees, and their tender branches. As a result of sun-burn, the affected parts crack and the bark peels off. The part so exposed gives access to insect borers. Trees affected by sun-burn and the borers do not grow normally, but remain stunted. Sun-burn can be prevented by taking care to see that the foliage of the

tree is distributed well on all sides so as to shade the branches during summer months. The stems exposed to the sun may also be covered with paper or straw, or coated with lime to avoid the burning effect. Sun-burn is common in the Poona district and damages nearly fifty per cent of fruits.

One of the causes which limit the extension of fig cultivation in the Deccan is the highly perishable nature of the fruit, which cannot be sent to distant markets without considerable loss. At the same time it is interesting to note that about 500,000 lb. of dried figs were annually imported into the Bombay Presidency alone from countries like Turkey, Persian Gulf, Afghanistan, Greece and California before the second world war. There is thus a market for figs in this country which is not fully supplied by home-grown fruits. Drying of figs, therefore, has a future as an industry, even if its scope be limited. Sound but fully ripe fruits after thorough washing, are cut into halves and exposed to sulphur fumes in a sulphur box for an hour and then dried on wooden trays either in the sun under dust-proof conditions as far as possible or in the home-drier at a temperature of 160°—165°F. The dried fruit is kept in sweating boxes (*i.e.*, air-tight containers), graded and wrapped in pliofilm paper bags just before marketing.

Sun-drying of figs

The Bombay Agricultural Department attempted some years ago to dry the Poona fig. The process adopted was simple. Ripe figs were picked carefully, and placed in single layers on suitable wire-gauze trays. These trays were then placed in an air-tight wooden chamber for about thirty minutes for fumigating with sulphur. Fumigation in this way was found to disinfect and bleach the fruits. The trays with fruits were placed one upon the other and flowers of sulphur were ignited below the lowest tray. As the fumes spread in the closed chamber the fruits get treated. In order to avoid over-fumigation the lowest tray was left empty. A suitable fumigation chamber for small scale operations is of the size of 3 ft. by 2 ft. and 2 ft. with cleats nailed to the sides of which, fruit trays can be slided in. The trays are 21 inches by 18 inches and made of wooden strips with best grade galvanised iron netting having one-fourth inch mesh. Such a chamber will hold about fifty pounds of fruits each time. Over-exposure to sulphur fumes

DRYING OF FIGS IN THE SUN.

In the foreground the fruits are being fumigated prior to drying. In the background are seen raised platforms on which fumigated fruits are spread out for drying.

Facing page 400.

causes figs to develop acidity, which is not desirable. Without fumigation, the final dried product lacks good colour.

After fumigation, fruits are exposed to the sun on wooden racks. Ordinary bamboo netting, three feet broad and four feet high, is found convenient for drying on a small scale. Figs kept for drying are turned repeatedly while drying, so as to allow them to dry uniformly on all sides. Drying in the sun is best done in the months of April and May. If rains threaten, the fruits are covered with water-proof canvas. Complete drying takes five to seven days. On drying, the figs become soft, pliable and semi-transparent, and are reduced to less than one-third their original weight. Over-dried fruits are leathery and tough. Dried figs contain eighteen to twenty-two per cent moisture.

The quality of figs dried in Poona was fair, though it did not come to the standard of the first grade Smyrna figs. In size, colour and softness of the meat, the fruits were very attractive. On analysis, they compared favourably with foreign products, as can be seen from the following figures:—

	Moisture per cent	Reducing sugar.
Sun-dried Poona figs.	19·25	45·95
Persian Fig I	19·45	46·30
Persian Fig II	19·90	45·70
Afghanistan fig	19·04	46·64
Grecian fig	19·14	46·50
Smyrna fig	19·25	57·31

The method of drying figs slightly differs in different countries, largely on account of difference in the quality of cultivated figs.

Figs are extensively dried in Turkey, Greece, Italy, France, Spain, Portugal, Egypt and California (15). In Asia Minor, figs are dried on drying floors. In Italy they are split lengthwise, dipped in boiling water for a moment and dried in the sun. In France, they are sweated for two days, after drying in the sun for two or three days after which they are again dried finally. In California figs are fumigated before drying in the sun. Before completely drying, figs are pulled flat as evenly and neatly as possible to economise packing space and to improve their appearance. Pulling is done by catching the

side of the fruit, so as to flatten it into a circular shape with the stalk and the eye in the centre on either side. Fruits are then graded according to their size and colour. Figs are then dipped in boiling brine (four ounce of salt in a gallon of water) for a few seconds. Fruits of the second grade particularly improve by this treatment. Dipping in brine makes the fruit soft and improves its taste. After dipping, the fruits are drained on a wire screen. Dried figs can then be packed for despatch to the market.

Fig jelly

Fully matured but slightly unripe fruit is cut into slices and covered with water and boiled for about half an hour so as to get a complete extract of pectin which is tested with jelmeter or with 95% alcohol and the degree of richness of the extract in pectin determined. The extract is strained through a coarse thick cloth. Calculated quantity of sugar is added to the clear extract and heated to a temperature of 222-223°F so that the jellying point is reached. The produce is poured hot into clean sterilized jars and then allowed to cool so that it sets well. After cooling, the surface is covered with a thin layer of paraffin wax to avoid spoilage of the jelly.

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CHAPTER X

BER OR BOR (*Zizyphus jujuba* Mill)

Introduction

Of late, the importance of "bor" is gaining ground. By nature the jujube or *bor* happens to be a hardy and easily grown fruit, requiring perhaps the minimum labour and attention of the farmer. It can also stand the roughest conditions of soil and climate. *Bor* trees are found in large numbers on the borders of fields and in uncultivated areas, where they grow without care and attention, except that when they are in fruits they are watched and fruit is harvested and sold. Until lately, regular planting of *bor* trees was not common, but realising their economic value increasing attention is being paid to them. As a result, the Bombay Department of Agriculture had had to deal with many enquiries on this fruit crop during the last few years and has rendered practical aid to growers, chiefly in the Gujerat and Khandesh districts, in budding several thousand wild plants with better commercial varieties. They have also shown the possibility of utilising the *Chani bor* (*Z. rotundifolia*) as a rootstock for raising superior varieties. The selection of a stoneless *bor* may give a great stimulus to *bor* cultivation in all parts of the Presidency.

Origin and distribution

The *bor* is an important indigenous fruit tree of India. It is known by the words, *bor*, *bari*, *ber*, *bory*, etc., in different places and in different languages. It is known as jujube or Chinese date in America. It generally occurs growing wild in several parts of India. A reference is made to its antiquity in this country by Babu Radhakant Deb in a paper found in the records of the Agri-Horticultural Society of Bengal in 1829. He stated that in early times the sages of Kashmir, near the banks of the Alacananda river lived on its fruits. Besides its abundance in the wild state, the large number of its known varieties and their extensive prevalence in almost all parts of the country not only proves its ancient domestication, but also establishes its indigenous reputation. *Bors* are widely grown in the eastern districts of the Punjab particularly

in Hansi and Gurgaon districts. More than a dozen commercial types of *bor* are found in this area. It is also fairly extensively grown in several districts of the Madras Presidency (500 acres), Bihar (6,000 acres), United Provinces (579 acres) and the Baroda State (2,200 acres) and also in Central Provinces. *Bors* are distributed on a wide area in the Bombay Presidency. In the Khandesh districts the cultivation of *bor* is concentrated in Shirpur, Erandol and Jalgaon talukas. It is also grown in Ahmednagar, Satara and Sholapur districts. In the Konkan tract some choice *bor* trees are found in the vicinity of Bombay town and Alibag. In the Gujerat districts seedlings of wild *bor* are grown on a fairly large scale, and budded *bors* are also gaining popularity.

The *bor* occurs in several temperate regions of both the hemispheres, and in the Tropical parts of Asia and America. Frank N. Mayer, Agricultural Explorer, was responsible for the introduction of scions of large fruited jujube varieties in the United States of America in 1908, and this work has now stimulated a great deal of interest in the culture of jujubes in California and Texas. It is largely grown in Afghanistan, Persia, Armenia, Syria, Burma, Malacca, Australia, Malay Archipelago, Mediterranean regions and China. It is said to have been introduced into the Eastern Islands of the Amboyna group by Ramphius. Its introduction in Arabia and Egypt seems to be recent. It is believed to have gone to Zanzibar from Asia. Jujube is an important fruit for dry Tropics, sub-tropics and arable areas. In Russia (12) its cultivation in the dry sub-tropical regions is given a place next to pistachio and almonds.

China is perhaps the most important country for the cultivation of jujubes. There the fruit is known as Chinese fig or Chinese date. There are hundreds of varieties of jujubes grown in China. It forms one of the principal fruits in Northern China, and has been cultivated there many centuries before the beginning of the Christian Era. David Fairchild (8), Agricultural Explorer of the United States of America, Department of Agriculture, wrote in 1918, "The Chinese jujube is practically a newly discovered fruit tree so far as American agriculture is concerned, for although, there are seedling jujubes in various public parks and door-yards, which doubtless are the result of early introductions through missionaries

in China, the importance of the large fruited grafted Chinese varieties was only begun in 1906". Some valuable observations have been recorded on this fruit by the Bureau of Plant Introduction in the United States of America. This Bureau seems to have succeeded in selecting suitable types for the American market. Dorsett (6) recorded in 1916, "The jujube from China is possibly as promising a plant commercially for California and the semi-arid south and south-west as any of the other valuable crops and ornamental plants that have been introduced from the Far East. The experimental tests made with this new alkali and drought-resistant fruit tree at the Chicago Plant Introduction Field Station to determine the possible value of strains and varieties that have been introduced from among the several hundreds known to exist in China, have been very satisfactory. The fruit of the better varieties is fully as large as a large prune, and reddish or mahogany brown in colour when ripe."

The *bor* trees attain a considerable size. It is observed in Central India that a tree measured about eighty feet in height, sixteen feet in girth at about five feet from the ground, and a girth of twenty-five feet at the base. In the Punjab and Madras, some varieties often attain great heights and girths of about ten feet. In Florida jujube trees attain heights of twenty-five to thirty feet (10). Some of the grafted varieties have gnarled stems and display a tendency to spread on the ground. The large dimensions attained by the trees in India as mentioned above, refer only to seedling trees. The trees in the Bombay Presidency are generally of a medium size, rarely attaining about half the size of the seedling trees in other parts of India. In regular seedling plantations in the Gujerat and Khandesh districts, the *bor* trees are smaller, because perhaps they are younger, than the isolated trees growing wild.

Varieties and classification

In Western India a study of the various varieties of *bor* has not yet been fully made, as the fruit is considered to be of comparatively minor importance. The chief horticultural types prevailing here are the small large-stoned round-fruited type, the large oval-fruited type and the stoneless small round-fruited type. The first type is the wild local variety, while the second is the more fleshy and popular cultivated one. The third type has lately been

discovered and is attracting the attention of the grower. It has no stone inside the fruit as its name indicates and it can be chewed whole. Besides the aforementioned chief varieties, there appear to be a number of less known varieties yet to be explored and exploited. A variety called *Kotho*, introduced from the Alwar State, is used for taking scions in the Jagudan tract of the Baroda State. The fruits of this variety are not much infested by insects, which are so common on other varieties. There is a good variety of *bor* known as *Meherun bor* near Jalgaon in the East Khandesh district which too is believed by some to be fairly resistant to fruit fly attack. In the Punjab several types of *bor* are reported to be under cultivation, especially in the dry parts of Gurgaon and Hansi districts testifying to the popularity of the fruit in those dry areas. A good deal of improvement in the choice varieties of the Punjab *bors*, seems to have been achieved during the Sikh rule, when perhaps no other fruit was within the easy reach of the general public. It is further believed that most of the choice trees were then protected in order to supply fruit to the Royal Household. There is a variety of *bor* which resembles in shape a chilli (*capsicum*) fruit, and is tasty even when green. This was introduced by one of the authors into Bihar from the Central Provinces during 1934. This variety has attracted some attention at Sabour.

Soil and climate

Bor trees thrive on a variety of soils and will grow and fruit in many ill-drained and poor soils, better than several other fruits. In California and Texas it is stated that the jujube grows luxuriantly on sandy loam soils, but appears to prefer slightly alkaline soils (21). Sandy loams which are neutral or slightly alkaline and are well cultivated are said to furnish the most suitable media for its growth and fruit production. The *bor* grows best in hot and dry climates. Excessive atmospheric humidity is a limiting factor in its successful cultivation in many parts of India. The difference in foliage, size and pubescence of leaves is emphasised by the ease with which the tree thrives even under conditions of drought and poverty of soil. Shallow light or medium black soils, with good drainage, are selected for planting *bor* in the Bombay Presidency.

In Russia, the jujube is propagated by seeds, cuttings from the

roots, and grafting. If propagated by seeds, the seed coat has to be broken or cracked, without injuring the embryo, otherwise *bor* seeds germinate after a long time.

Propagation

In California, *bor* seeds are often stratified in sand and kept in a warm place for three or four weeks before they are sown. Thomas (21) reports little success in rooting the stem cuttings. Root cuttings of four to six inches, and having a diameter of not less than three sixteenth of an inch were successfully rooted. Budding proved unsatisfactory in the United States of America, but has been found to be an easy matter in the Punjab and other parts of India where even ring or flute budding has been successfully practised. Most successful method of propagating the jujube is by whip grafting. Bench and Field grafting are both followed. The latter is somewhat slower but the plant can be secured at less cost by this method. The wood used for grafting should be the past season's growth. It should not be much smaller than a lead pencil as smaller wood does not produce good plants. The small side branches which bear the leafy deciduous branches are not suitable for scions. After grafting, it should be carefully tied with raffia, waxed, and allowed to callus in damp moss in a place having a temperature of 40°-50°F. In about 3 to 4 weeks the callusing will have progressed sufficiently to allow planting in the nursery. The plants should be planted in the nursery and the grafts completly covered with soil by heaping soil arround it. This will prevent drying out and is absolutely essential for success. In the Punjab, the jujube is a regular nursery plant in many places. Rootstocks of wild jujube plants are carefully raised and budded to choice varieties. Budded *bor* plants are sold like grafts of other fruit trees such as mango and orange.

In Western India the *bor* has so far been commonly propagated by seeds. Of late, budding of choice varieties on wild rootstocks is gaining popularity.

Budding of *bor*

As a result of trials made here during the last few years it has been found that all wild plants of *bor* and *Chani bor*, in the districts of Surat and Ahmedabad can be worked upon with buds of choice varieties. The method of budding is simple. Plants are headed back in the months of February or March, leaving about a foot of the stem above the ground. From below the cut end,

new sprouts arise. The strongest shoot alone is retained, and the others are cut out. When this shoot develops a thickness of half an inch at the base it can receive a bud. It generally takes about two months for such sprouts to be ready to receive the bud. It is, therefore, sometime in the month of April or May that budding operations commence. Buds are selected from one season wood of the choice kind. Bud-sticks are immersed in water for a few hours before the buds are removed for use. If the buds remain green for a period of seven to eight days after insertion, it can be taken for granted that they are "taking". Ten days after budding, if the buds continue to be green, the rootstock is cut off about four inches above the point of insertion of the bud. Buds sprout after about twenty days. When the bud growth is about six inches long, its terminal bud is nipped off to encourage lateral branching. Within a year this growth develops into a small tree, which can yield a harvest of about four to six pounds of fruit.

Culture and pruning

In the Gujerat districts one-year-old seedlings are budded in December in the orchard site. The local practice is to plant seedlings of wild variety in the orchard sites at twenty feet distance from each other. A year later these are budded upon, as pointed out above, during the month of December. Budded rootstocks have to be properly earthed up and a basin made around their stem to give support to the stem and to hold rain water. The plants are manured soon after the buds sprout at the rate of two or three baskets (40—60 lb.) farm yard manure. At the beginning of the monsoon, two pounds of common salt are given to each tree, and the growers raise a circular mound of earth to strengthen the base of trees to withstand strong winds. Ploughing between rows of trees is done once in the month of September. In the first few years of the plantation, an inter-crop of castor (*Ricinus communis*) is grown. Where there is no regular plantation, the self-sown seedling trees are pruned close to the ground in the month of May. The new sprouts that spring up are budded upon with scions of superior varieties in the month of July, after the atmosphere is moistened by the first rains. Pruning can be practised on the branches of *bor* trees once in two years, more or less in the same manner as the grape vines or guava plants are pruned. Smaller shoots are pruned back to their base leaving a short

stump. This forces new fruit spurs and increases the yield. There is no regular cultivation of *bor* in any of the Deccan and Konkan districts. *Bor* is generally grown in Konkan for hedging purposes. In some places in the Satara district it is complained that the wild *bor* trees on which superior varieties have been budded, put forth vegetative growth only, and bear fruits sparingly. This seems to be due to the fact that the wide expanse of the root system of the rootstock tree brings ample nourishment to the new bud growth, which takes some time before it matures sufficiently to bear fruits. Treating such trees with a heavy dose of bone meal about the beginning of the monsoon may be found useful to induce them to fruit.

Bearing

The seedlings usually begin to bear from the third or the fourth year. *Bor* trees flower in June. The fruits ripen in the cold weather in the Central Provinces and are available in the market from the beginning of November (13). It is almost the only fruit in the market in February and March, after the orange season has closed, and other fresh fruits become scarce. December to April is the bearing season for *bors* in South India. *Bor* is, therefore, specially prized because of its availability in seasons of scarcity of other fruits. In Florida (10) jujubes ripen from July to September.

Chani bor

Side by side with the varieties of *Zizyphus jujuba* another wild bush of the same genus, known as *Z. rotundifolia* grows extensively in Gujerat. It is seen growing very commonly in the Northern Gujerat. In the districts of Ahmedabad, it is a common bush in the wilds. It seems to flourish on all sandy slopes and is extremely xerophytic in character. Its habit is straggling. It rapidly grows by means of root buds. It covers large circular patches and is often considered an obnoxious weed by cultivators. Every year it is cut, but it is difficult to eradicate it. Instead, the stump grows with redoubled vigour. It has small leaves and possesses sharp prickles in pairs on its twigs. Like many other wild bushes it does not even make a good fuel. It bears very small fruits with little edible pulp, which is acidic in taste. It is the shepherd or the cow-boy who might value this fruit in normal years. During famine days, however, the fruit is collected by villagers for "*Barchumi*"* purposes. *Z. rotundifolia* is thus essentially a

*It is ground and used as meal.

STONELESS *BOR* TREE. *Facing page* 413.

weed. During the past few years this wild plant has been tested for its value, as a rootstock for choice varieties of *bor*, the cultivation of which is much desired in the Gujerat division. Observations extending over many years now lead to the conclusion that this obnoxious weed as it is considered, makes a very valuable rootstock for the *Z. jujuba* and its varieties. This wild shrub takes the bud very readily and the budded plants require little further care, except protection from strong winds, to grow and bear fruits. The quality of fruits produced is very satisfactory and fetches as much value as fruit of similar varieties raised on *Z. jujuba* rootstocks. In fact, plants budded on this rootstock are easier to handle as they do not grow into large trees. Whether this dwarf habit of the trees is due to the influence of the rootstock remains to be investigated. The method that has been adopted successfully in budding this bush does not materially differ from the one adopted in budding *Z. jujuba* plants. This bush is headed back right to the level of the ground in the months of February and March. Several vigorously growing young shoots are thrown up and in the months of April and May these young shoots are budded at a height of about a foot from the ground. The 'T' method of budding is found successful. All shoots which might sprout from time to time near and below the bud from the rootstock are nipped off. When the bud grows into a shoot, five or six feet in length, the plant is earthed up to give strength against strong winds. The budded bushes bear fruit in three years. Fruit is harvested from December to middle of February. After harvesting is over in April and May the budded plants are pruned. All growth is cut down to the base from where new sprouts develop vigorously and bear good fruit next season. Each bush thus budded fetches an income of about a rupee per season.

Stoneless *Bor*

The Bombay Department of Agriculture has recently observed that there exists a variety of *bor*, in which the endocarp of the seed does not develop into a hard stone as is usual with seeds of the common varieties. The fruit of this variety is round and small in size like that of the wild type, but one hardly feels the stone inside it while chewing the ripe fruit. This fruit dries well. The original tree of the stoneless variety is growing near the Surat city. The Ganeshkhind Fruit Experiment Station, Kirkee, has now raised trees of

this type and can supply bud sticks to the public. During the last few years, a large number of these buds have been distributed to cultivators in the various parts of Western India.

The *bor* tree is not only the source of a much relished fruit but yields other economic products as well. The Chinese jujube (21) is utilized in a number of ways. Fruits are eaten fresh, semi-dried, baked in bread, stewed with rice, millet or meat. As a candied or crystallized fruit, it is very delicious. In the United Sates of America and China, it is extensively used as a sweet after the fruit is cooked in syrup, which procedure is also involved in candying or crystallizing it, after puncturing the thick skin thoroughly and all over to permit the penetration of the syrup. The leaves of *bor* are used as fodder to feed livestock and are said to increase the milk yield of milch cattle. This belief of farmers has yet to be confirmed by experimental data but it seems to be a well established fact in the case of sheep and goats. The question of fodder supply during periods of fodder scarcity engages a good deal of attention of the agricultural population of India. It is observed all cattle eat *bor* leaves with relish. The chemical analysis of *bor* leaves disclose that they contain high phosphoric acid and a large amount of mucilaginous matter. There appears to be nothing in them which would make them objectionable as a fodder. Although these leaves may not compare favourably with other fodders like maize, they are certainly valuable as an emergency fodder. The phosphatic contents of young fruits before they develop stones, cannot but enhance the fodder value of leaves mixed with tender fruits. The thornless varieties with a large leaf surface are more suitable for use as fodder than the thorny *Malla* or *chani bor*.

Uses of the *bor* tree

In all parts of India (24), the *bor* tree is known for the quality of its wood. Persian wheels, agricultural implements, well-curves, oil seed crushers, legs of bedsteads and various other articles are made of its wood. It is also considered a valuable timber for constructing huts and buildings. This wood is considered to be fine and close-grained. It makes excellent charcoal and has a high calorific value. In the districts of Satara, the branches of *bor* are used for fencing purposes by the villagers. As they are thorny and cheaply available, their use in hedges is

highly appreciated. The extension of the cultivation of *bor* in the Deccan and dry-rainless tracts might serve a useful purpose in the present campaign of rural uplift as this tree is a source of fruit, fuel, fodder and fencing.

Data obtained indicate that by proper addition of acid and pectin, a good jelly which still retains a fairly large amount of ascorbic acid can be made from jujubes (fruit of *Zizyphus vulgaris*). They also suggest the possibility of using this fruit in combination with other fruits as a means of increasing the ascorbic acid content of the product (20).

Harvest and storage

With the exception of some varieties, which lend themselves to be eaten even in their greenish state, the *bor* as a rule should be picked, when they are still crisp, but have developed a light yellowish scarlet or brownish hue on the outer skin. Wardlaw (23), summarising the findings of other workers, suggests that jujubes should be picked when the first brown spot appears on the skin. The small fruits borne on the seedling jujube trees in this country are, however, fit to be eaten only when the flesh is soft to the touch and the skin has attained the full colour. Overholser and others (17) have found that at 32°F jujubes can be stored in open containers for 45 days, but the skin cracks and wilts, when the fruits are kept in closed containers.

Food value

Blasdale (1) gives the average composition of the pulp of dried jujube from the Chinese Quarter of San Francisco. Church (5) reports the results of physical and chemical examinations of the pulp of fresh and dried jujubes grown at the U. S. Plant Introduction Garden, Chico, California. (Also see pages 416, 417 and 418.)

Percentage of ash in the seed-free pulp of two varieties and analyses of ash are here given. The high alkalinity of the ash is shown by the marked predominance of basic constituents.

Commercial value

The *bor* is a dry crop and little attention is paid to it, excepting ploughing and cleaning the area of the plantation in some tracts like Khandesh only. The land used for this crop is generally inferior, where perhaps other fruit crops would not be successful. It is difficult to state with accuracy the exact cost of cultivation in detail, as *bor* trees are mostly scattered about. There is, however, little doubt that the cost of cultivation is very low in comparison with

Composition of jujube pulp

	Samples	Water	Protein	Fat	Acids as Citric	Sugars reducing	Sucrose	Pectin	Fibre	Ash
		%	%	%	%	%	%	%	%	%
Blasdale										
Dried	1	13·44	2·93	—	—	42·19	13·06	—	—	1·73
Church										
Fresh	10	65·36	1·16	0·28	0·43	11·91	12·22	0·36	1·27	0·85
Dried	4	16·24	4·42	—	1·15	39·24	2·78	—	3·17	2·32

Composition of Ash of Jujube pulp

	Ash	K_2O	Na_2O	CaO	MgO	Fe_2O_3	MnO	P_2O_5	SO_3	SiO_2	Cl.
	%	%	%	%	%	%	%	%	%	%	%
I	1·03	56·40	1·65	5·42	4·46	0·12	1·11	1·04	1·85	0·28	4·08
II	1·42	54·78	1·29	5·60	3·53	0·12	0·99	0·64	1·40	0·27	3·49

Benoy quoted by Winton and Winton (25).

The food value of *Ber* (*Zizyphus jujube*) in India is given in the following table :

Name of food	Ber Zizyphus
Botanical Name	*Zizyphus jujube*
Moisture %	85·9
Protein %	0·8
Fat (Ether extractives) %	0·1
Mineral matter %	0·4
Fibre %	—
Carbohydrates %	12·8
Calcium (Ca) %	0·03
Phosphorus (P) %	0·03
Iron (Fe) mgs. %	0·8
Calorific value per 100 gms.	55
Carotene (International Vitamin A Unit per 100 gms.)	70
Vitamin B (I.U. per 100 gms.)	—
Vitamin C mgs. per 100 gms.	—
Calories per ounce	16

the income. The yield of a fairly grown *bor* tree ranges from two to three or even more maunds of fruits annually. The large oval fruit fetches a high price.

Pests and diseases: fruit fly

The *bor* trees are infested with several kinds of insect pests, but the commonest are the fruit borers. Fruit Fly, *Carpomyia vesuviana.* B is the most harmful, particularly to sweet varieties. A few eggs are laid at a time in each fruit. A single fly may lay eggs in a large number of fruits. The eggs are small, elongated, pointed at both ends, and white in colour. On hatching, the maggot burrows into the fruit and remains feeding inside and resembles a grain of fine rice when fully grown. The maggot goes on feeding on the pulp and makes small holes in the rind of the fruit to admit air for respiration. Bigger holes indicate that the full-grown maggot, has come out from the fruit for pupation in the soil. The pest is active from November to March, during which period two or three broods appear. It hibernates in the pupal stage in the soil during summer. Pupation takes place at different depths according to the condition of the soil control:—

1. After the fruiting season the surface of the soil underneath the tree should be burnt by spreading dry grass and leaves so as to kill the pupae.
2. If possible bait spray of lead-arsenate powder 4-5 ozs., sugar or molasses four pounds, water three gallons may be tried during the prevalence of the fly. Commence spraying about three weeks before the fruit ripens and keep on baiting every twelve days and always repeat after rains. Spray for some time even after the fruit is harvested.

It may be possible to spray small plants where the *Chani bor* is used as rootstock.

No serious damage is reported on *bor* trees from fungus diseases in Western India, except from a species of *Cladosporium* which attacks only the leaves.

Lac rearing on *bor* trees

The *bor* tree is used for rearing lac insects (*Tachardia laccad.*) in the Central Provinces and in Madras Presidency. Some observations in this direction are also made in the Bombay Presidency. The wild *bor* forms a useful host plant for the lac insect (19, 15, 16). It is expected that in due course of time, when the

price of shellac in the world market improves, the use of wild *bor* in India will be fully realised by the cultivators. Lac rearing has attained most prominence in Bihar than in any other province not excluding the Central Provinces.

Candied *Bor*

Large sized fruits which have just begun to turn yellow are pricked with any suitable hand-worked device which has a large number of thick pinlike prongs sticking out. This pricking is followed by salt curing by steeping in 2% salt solution, adding calculated amounts of salt so as to increase the strength of brine by 2% every 24 hours till a final concentration of 8% brine is reached. The salt cured fruit is then boiled till it becomes soft. It is washed thoroughly to remove the salt absorbed. The fruit is then put in boiling syrup of 38° Brix containing 0·1% citric acid which is again brought to a boil and the vessel well covered. The strength of the dipping syrup is increased to 35°, 40°, 45°, 50°, 55°, 60° after every 24 hours and later to 65°, 70°, 75° after every 48 or 72 hours. The syrup is then drained and the candied fruit dried on wire gauze trays preferably in the shade.

Drying of *Bor*

Fully ripe fruit is washed and given a little dip in boiling water, drained and left in the trays to dry in the sun. Efforts should be made to provide hygienic conditions for drying. It takes about 8-10 days for the fruit to dry. The dried fruit tastes very sweet and is relished very much as a desert fruit.

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END

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